From:	Ohrel, Sara
To:	Ohrel, Sara
Sent:	7/25/2014 10:41:39 AM
Subject:	deliberative
Attachments:	Framework_Report_all comments_7 25_v2.docx

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email and its content are deliberative--do not distribute or cite--

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---

In my comment bubble on the last slide [**Ex. 5 - Deliberative**]

Ex. 5 - Deliberative Sorry for any confusion.

Melina Williams | US EPA | Office of General Counsel | Air and Radiation Law Office | Mail Code 2344A | phone: (202) 564-3406 | fax: (202) 564-5603

The contents of this e-mail and any attachments to it may contain deliberative-process, attorney-client, attorney work product, or otherwise privileged material. Do not distribute outside of EPA or DOJ.

From: Williams, Melina
Sent: Wednesday, July 23, 2014 6:16 PM
To: Mangino, Joseph; Ohrel, Sara; Doster, Brian; Jordan, Scott; Hoffman, Howard; Lie, Sharyn; Camobreco, Vincent; Santiago, Juan; Kornylak, Vera S.; Culligan, Kevin; Levy, Aaron; Montanez, Jessica; Stenhouse, Jeb; Deck, Leland
Cc: Kocchi, Suzanne; Fawcett, Allen; Irving, Bill; Cole, Jefferson
Subject: RE: slides for Monday biomass briefing with Janet - deliberative

Hi Sara,

I had a few additional comments / suggestions, which I put on top of AQPD's, in purple ink with a few comment bubbles. I'm in tomorrow, if you'd like to discuss any of my comments, but I have an offsite meeting from 9:45 to 11:45ish. This doesn't reflect Brian's review.

Thanks,
Melina

Melina Williams | US EPA | Office of General Counsel | Air and Radiation Law Office | Mail Code 2344A | phone: (202) 564-3406 | fax: (202) 564-5603

The contents of this e-mail and any attachments to it may contain deliberative-process, attorney-client, attorney work product, or otherwise privileged material. Do not distribute outside of EPA or DOJ.

From: Mangino, Joseph
Sent: Wednesday, July 23, 2014 12:23 PM
To: Ohrel, Sara; Doster, Brian; Williams, Melina; Jordan, Scott; Hoffman, Howard; Lie, Sharyn; Camobreco, Vincent; Santiago, Juan; Kornylak, Vera S.; Culligan, Kevin; Levy, Aaron; Montanez, Jessica; Stenhouse, Jeb; Deck, Leland
Cc: Kocchi, Suzanne; Fawcett, Allen; Irving, Bill; Cole, Jefferson
Subject: RE: slides for Monday biomass briefing with Janet - deliberative

Hi Sara,

Attached is a version of your slides with OAQPS/AQPD comments inserted. These reflect combined comments from Juan, Vera, Jessica, and myself. Since PowerPoint doesn't have track change, I used strikeout and inserted our edits in RED. Where there are brackets, those reflect questions or comments related to the bullet. Also, in the 111d slide there is bubble comment included.

Please note that Kevin Culligan of OAQPS/SPPD is also looking at the 111(d) slide so you may receive feedback from him on that one as well.

Thanks for the opportunity to look at these and please let me know if you have any questions on our comments.

-Joe

Joe Mangino
U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Policy Division
Research Triangle Park, NC
919-541-9778 (phone)

Note: Positions or views expressed here do not represent official EPA policy. Interagency deliberative and confidential.

From: Ohrel, Sara
Sent: Wednesday, July 23, 2014 9:51 AM
To: Doster, Brian; Williams, Melina; Jordan, Scott; Hoffman, Howard; Lie, Sharyn; Camobreco, Vincent; Santiago, Juan; Kornylak, Vera S.; Culligan, Kevin; Koerber, Mike; Mangino, Joseph; Levy, Aaron; Montanez, Jessica; Stenhouse, Jeb; Deck, Leland
Cc: Kocchi, Suzanne; Fawcett, Allen; Irving, Bill; Cole, Jefferson
Subject: slides for Monday biomass briefing with Janet - deliberative
Importance: High

Hello everyone,

In preparation for our meeting with Janet on biogenic emissions on Monday, we are sending you our draft slides. We need to finish edits and send the PPT to the OAR IO tomorrow, so please send us your suggested edits no later than close of business today.

Thank you,
Sara

Sara Bushey Ohrel
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Climate Change Division
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Cell: (202) 341-6748

-- this email and its contents are deliberative--do not distribute or cite --

deliberative

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Cell: (202) 341-6748

--this email and its content are deliberative--do not distribute or cite--

From:	Hanks, Katie P.
To:	Ohrel, Sara
CC:	Baker, Justin
Sent:	7/18/2014 4:58:40 PM
Subject:	App G
Attachments:	Appendix_G_Process_Attributes_oaqps_mkw_tb_so_Rev7-16-14.docx; Framework_Master_5 01 2014_clean_Final_Revised_7-16-14.docx

I went through appendix G and attempted to address the comments from OGC and others. This version has my responses to the comments with suggested edits to incorporate the comments. Consistency in terminology was a theme in the App G comments. I looked at the May 1 main framework document and Appendix F to try and address those questions. I may be suggesting terminology different from the solutions EPA is working on for App F and the main framework document so I wanted to get you my comments in case any of these ideas help with EPA's consistency review of the other pieces.

I would be happy to create a cleaner version of App G to remove bubbles that have been addressed. My comments in the bubbles, along with the additional related comments I added make it hard to read through.
I'm including a few comments on the main document related to my edits/comments in App G.

Please let me know how you would like for me to proceed with this.

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

FYI

From: Fawcett, Allen
Sent: Thursday, July 17, 2014 9:58 AM
To: Ohrel, Sara
Cc: Cole, Jefferson
Subject: RE: concept characterization

Here are my thoughts. Let me know if this is helpful.

Thanks,
Allen

Ex. 5 - Deliberative

From: Ohrel, Sara
Sent: Wednesday, July 16, 2014 5:51 PM
To: Fawcett, Allen

Subject: concept characterization

Hi Allen,
Can you check this to see if I have the general concept correct? If not, please set me straight.

> # Ex. 5 - Deliberative

Thanks.
And thanks again for all the support and patience today. It is deeply appreciated.

Sara

Sara Bushey Ohrel
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Climate Change Division
U.S. Environmental Protection Agency
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Cell: (202) 341-6748

--this email and its content are deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	DeLuca, Isabel
Sent:	7/17/2014 10:02:01 AM
Subject:	RE: please send latest version of the report to isabel - DELIBERATIVE
Attachments:	Biomass update with Anna and Paul 2 4 14.pptx; Main SAB Presentation_10_25_2011_final2.pptx; Sessions staff briefing 1 28 2014F.pptx

1. PPT we gave at SAB meeting in 2011 on first framework (for background – things have changed in the framework, but including in case you are interested)
2. PPT we gave on the Hill (high level, broader context)
3. PPT we gave to Anna and Paul in February – internal only

From: DeLuca, Isabel
Sent: Thursday, July 17, 2014 9:54 AM
To: Ohrel, Sara
Cc: Kocchi, Suzanne; Cole, Jefferson
Subject: RE: please send latest version of the report to isabel - DELIBERATIVE

Sure—if you have a summary ppt that'd be great too. Thanks!

From: Ohrel, Sara
Sent: Thursday, July 17, 2014 9:53 AM
To: DeLuca, Isabel
Cc: Kocchi, Suzanne; Cole, Jefferson
Subject: RE: please send latest version of the report to isabel - DELIBERATIVE

Ok. Please let me know if you have questions and/or if you would like some PPTs we have on this to help distill it into digestible pieces J

From: DeLuca, Isabel
Sent: Thursday, July 17, 2014 9:51 AM
To: Ohrel, Sara; Kocchi, Suzanne; Cole, Jefferson
Subject: RE: please send latest version of the report to isabel - DELIBERATIVE

Thanks, Sara. This is perfect. Just trying to get a sense of what's in here.

From: Ohrel, Sara
Sent: Thursday, July 17, 2014 9:36 AM
To: Kocchi, Suzanne; Cole, Jefferson
Cc: DeLuca, Isabel
Subject: RE: please send latest version of the report to isabel - DELIBERATIVE

Sure. Attached is the clean version we sent for internal review May 1. I can send you the most current version if you really want it, but it is all marked up and I wouldn't wish it upon anyone – but please let me know if you want that version too.

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

From: Kocchi, Suzanne
Sent: Wednesday, July 16, 2014 3:07 PM
To: Ohrel, Sara; Cole, Jefferson
Cc: DeLuca, Isabel
Subject: please send latest version of the report to isabel

Can one of you please send the latest version of the main document to Isabel? I know you said you were still working on some things but Isabel wants to familiarize herself with what's in it so whenever you get a chance please shoot her the file. Thanks!

From:	Baker, Justin
To:	Ohrel, Sara
CC:	Cole, Jefferson; Latane, Annah
Sent:	7/16/2014 2:58:18 PM
Subject:	RE: BL - deliberative
Attachments:	Black_liquor4-18-14_rev7-7-14so_jb.xlsx

this email and all attachments are deliberative

Sara,

I've filled in the following values for the black liquor case study. What I've done is Ex. 5 - Deliberative

Ex. 5 - Deliberative

I'm happy to discuss more on our call. I also attached the revised Excel file with my calculations.

Justin

Ex. 5 - Deliberative

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Monday, July 14, 2014 3:31 PM
To: Baker, Justin
Cc: Cole, Jefferson
Subject: BL - deliberative

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
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Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Ohrel, Sara
Sent:	7/16/2014 7:34:56 PM
Subject:	delberative
Attachments:	Biomass update for Janet 7 16 14 v1.pptx

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

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From:	Ohrel, Sara
To:	Justin Baker (justinbaker@rti.org)
CC:	Cole, Jefferson
Sent:	7/15/2014 8:57:59 AM
Subject:	app g process attributes - deliberative
Attachments:	Appendix G so.docx; Appendix_G_Process Attributes oaqps mkw tb so.docx

Hi Justin,

Attached is App G on process attributes. There are a lot of good comments from Melina (OGC) and a few from OAQPS and Thomas. It looks overwhelming but I think we can easily answer most questions (and I ask that we do so in response comment bubbles), and many of Melina's edits are improvements. The main issue in this app is definitions – we need to carefully cross walk definitions here and App F on the equation and the main doc. We will be reviewing App F soon and will send that along for your use, hopefully with the main doc (or at least part of it) shortly after. In the meantime, other edits/comments can be addressed.

I am also including the old version of this – there are loads of edits but not too many 'next round' comments. the ones I found in a quick skim were **Ex. 5 - Deliberative**

Ex. 5 - Deliberative Please at least flag these issues in the updated doc and we will see if we can address in a timely manner.

Thanks,

Sara

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Justin Baker (justinbaker@rti.org)
CC:	Cole, Jefferson
Sent:	7/14/2014 4:50:04 PM
Subject:	FABA apps - deliberative
Attachments:	Appendix_J_Anticipated Baselines Background_5 1_oaqps.docx; Appendix_K_Anticipated Baseline Construction Methods_5 1_oaqps.docx; Appendix_L_Anticipated Baseline Case Studies_5 1_oaqps.docx

Hi Justin,
Attached you will find FABA Apps J, K, L. There are not many comments on these apps.

Please address the comments in bubbles – this can include edits to the document to address comment and response comments within bubble. Even if you do not make text edits per a comment, please respond to the comment in the bubble to answer the comment/explain why we did something a certain way. For comments where you would like EPA feedback or to discuss with us, please identify those and we can discuss them (no later than Thursday am).

Please let me know if you have any questions.
Thank you,
Sara

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Cole, Jefferson
To:	Ohrel, Sara
Sent:	7/10/2014 2:24:07 PM
Subject:	OAQPS App G comments - task list from this afternoon
Attachments:	Appendix_G_Process Attributes 5 1_oaqps.docx; biomass task list (abbrev) 2014.07.10.docx

Sara,

Here are both of the attachments we discussed. The first is the May 1 version of Appendix G with OAQPS's comments put in. The other is the quick word doc I threw together with various tasks we discussed.

Thanks,

Jeff

Jefferson Cole
Economist
Climate Change Division
U.S. EPA
202.343.9671
cole.jefferson@epa.gov

From:	Ohrel, Sara
To:	Hanks, Katie P.
Sent:	7/8/2014 12:38:26 PM
Subject:	RE: BL question

Perfect – thank you!

From: Hanks, Katie P. [mailto:kphanks@rti.org]
Sent: Tuesday, July 08, 2014 11:37 AM
To: Ohrel, Sara
Subject: RE: BL question

I got your voice mail. _Ex. 5 - Deliberative_

Ex. 5 - Deliberative

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Tuesday, July 08, 2014 7:50 AM
To: Hanks, Katie P.; Beach, Robert H.
Cc: Baker, Justin
Subject: Re: BL question

Hi Kate,
Can you please send me _Ex. 5 - Deliberative_

Ex. 5 - Deliberative

Thanks!

Sent from my BlackBerry 10 smartphone.

From: Hanks, Katie P.
Sent: Monday, July 7, 2014 5:03 PM
To: Ohrel, Sara; Beach, Robert H.
Cc: Baker, Justin
Subject: RE: BL question

Ex. 5 - Deliberative

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Monday, July 07, 2014 1:56 PM
To: Hanks, Katie P.; Beach, Robert H.
Cc: Baker, Justin
Subject: RE: BL question

Thanks Katie. | Ex. 5 - Deliberative |
| Ex. 5 - Deliberative | Maybe I am missing something, so I will call you. thanks!

From: Hanks, Katie P. [mailto:kphanks@rti.org]
Sent: Monday, July 07, 2014 1:29 PM
To: Ohrel, Sara; Beach, Robert H.
Cc: Baker, Justin
Subject: RE: BL question

Ex. 5 - Deliberative

| Ex. 5 - Deliberative | Is this what is needed? If not, we may need to chat for a minute so I can understand the question a little better.

Katie Hanks
RTI International
3040 Cornwallis Road
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(919) 316-3732
(919) 541-7155 (fax)

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Monday, July 07, 2014 12:15 PM
To: Hanks, Katie P.; Beach, Robert H.
Cc: Baker, Justin
Subject: RE: BL question

Perfect, thanks.
One more request – | Ex. 5 - Deliberative |
| Ex. 5 - Deliberative | Please let me know if you can today.

From: Hanks, Katie P. [mailto:kphanks@rti.org]
Sent: Monday, July 07, 2014 11:44 AM
To: Ohrel, Sara; Beach, Robert H.
Cc: Baker, Justin
Subject: RE: BL question

Ex. 5 - Deliberative

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Monday, July 07, 2014 11:31 AM
To: Hanks, Katie P.; Beach, Robert H.

Cc: Baker, Justin
Subject: BL question

Hi Katie,

I hope you had a nice 4th holiday!
I have a quick request for you – I know within the black liquor paper you had some numbers for the

Ex. 5 - Deliberative

Thank you!

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

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From:	Hanks, Katie P.
To:	Ohrel, Sara; Beach, Robert H.
CC:	Baker, Justin
Sent:	7/8/2014 8:13:22 AM
Subject:	RE: BL question
Attachments:	Black_liquor4-18-14_rev7-7-14.xlsx

Ex. 5 - Deliberative

I'm going to be away from my computer until ~9:45.

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Tuesday, July 08, 2014 7:50 AM
To: Hanks, Katie P.; Beach, Robert H.
Cc: Baker, Justin
Subject: Re: BL question

Hi Kate,
Can you please send me

Ex. 5 - Deliberative

Ex. 5 - Deliberative

Thanks!

Sent from my BlackBerry 10 smartphone.

From: Hanks, Katie P.
Sent: Monday, July 7, 2014 5:03 PM
To: Ohrel, Sara; Beach, Robert H.
Cc: Baker, Justin
Subject: RE: BL question

Ex. 5 - Deliberative

Katie Hanks
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Research Triangle Park, NC 27709
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(919) 541-7155 (fax)

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Monday, July 07, 2014 1:56 PM

To: Hanks, Katie P.; Beach, Robert H.
Cc: Baker, Justin
Subject: RE: BL question

Thanks Katie. | Ex. 5 - Deliberative
| Ex. 5 - Deliberative | Maybe I am missing something, so I will call you. thanks!

From: Hanks, Katie P. [mailto:kphanks@rti.org]
Sent: Monday, July 07, 2014 1:29 PM
To: Ohrel, Sara; Beach, Robert H.
Cc: Baker, Justin
Subject: RE: BL question

Ex. 5 - Deliberative
| Ex. 5 - Deliberative | Is this what is needed? If not, we may need to chat for a minute so I can understand the question a little better.

Katie Hanks
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(919) 541-7155 (fax)

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Monday, July 07, 2014 12:15 PM
To: Hanks, Katie P.; Beach, Robert H.
Cc: Baker, Justin
Subject: RE: BL question

Perfect, thanks.
One more request – | Ex. 5 - Deliberative
| Ex. 5 - Deliberative | Please let me know if you can today.

From: Hanks, Katie P. [mailto:kphanks@rti.org]
Sent: Monday, July 07, 2014 11:44 AM
To: Ohrel, Sara; Beach, Robert H.
Cc: Baker, Justin
Subject: RE: BL question

Ex. 5 - Deliberative

Katie Hanks
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3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Monday, July 07, 2014 11:31 AM
To: Hanks, Katie P.; Beach, Robert H.
Cc: Baker, Justin
Subject: BL question

Hi Katie,

I hope you had a nice 4th holiday!

I have a quick request for you – I know within the black liquor paper you had some numbers for the

Ex. 5 - Deliberative

Thank you!

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
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Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Cole, Jefferson
To:	Ohrel, Sara
Sent:	7/7/2014 3:32:11 PM
Subject:	More PR materials
Attachments:	biogenic GHG accounting timeline 3.21.2011.pdf; Determination memov7.docx; EPA Peer Review Handbook.pdf; EPA Science Policy Council Assessment Factors.pdf; EPA_InfoQualityGuidelines.pdf; GHG accounting SOW 2.24.2011.pdf; ICF email acknowledging receipt of guidelines.pdf; ICF Submission in Response to Request No. 150 under EPA Contract Number EP-W-07-068.pdf; ISI Determination from Gina.pdf; Memo from Gina McCarthy to Vanessa Vu.pdf; OMB Peer Review Bulletin.pdf; SAB panel process.pdf; SAB public participation.pdf; SAB wide solicitation of panel.pdf; TO 092_Memorandum_QA-QC_08-18-2011_v1.0.docx

Jefferson Cole
Economist
Climate Change Division
U.S. EPA
202.343.9671
cole.jefferson@epa.gov

From:	Cole, Jefferson
To:	Ohrel, Sara
Sent:	7/7/2014 2:45:07 PM
Subject:	RE: BL piece - deliberative
Attachments:	Possible black liquor treatment options 7 7 14 jc.docx

Sara,

Thanks for your patience. I think this looks good. I've included a few minor comments and edits.

Best,

Jeff

From: Ohrel, Sara
Sent: Monday, July 07, 2014 1:03 PM
To: Cole, Jefferson
Subject: RE: BL piece - deliberative

If you can send by 3pm, I can wait. Then I can still send soon thereafter. Next up will be the project overview 1-2 pager also for the Paul meeting.

From: Cole, Jefferson
Sent: Monday, July 07, 2014 1:01 PM
To: Ohrel, Sara
Subject: RE: BL piece - deliberative

Hi Sara,

I probably wouldn't be able to get you back comments until 2:30pm or 3pm.

If that is too late, please feel free to send it along without my comments.

Thanks,

Jeff

From: Ohrel, Sara
Sent: Monday, July 07, 2014 12:58 PM
To: Cole, Jefferson
Subject: BL piece - deliberative

HI Jeff,
I hope you had a good 4th!!!
Attached is the draft BL piece for Paul. I would like to send this to the chiefs this afternoon so please send any comments/suggestions you may have.
Thanks!

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
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Phone: (202) 343-9712
Cell: (202) 341-6748

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Hopefully it helps!

Per the meeting, the Paul one-pager is on timing etc but also on next steps for AF2 as well as general workplan for how to move forward in 111d context: what we have planned and possible work/modeling ideas, and what we have $$ for vs stuff that would require more $$.

Here is an updated version. Ok for now? Once we have this done to inform development of the Paul one pager, I can work on that. Now, I am working on black liquor. You?

From: Cole, Jefferson
Sent: Thursday, July 03, 2014 1:33 PM
To: Ohrel, Sara
Subject: RE: tasks and schedule - deliberative

I see. Thanks for the clarification. I thought this was to send back to The Chiefs ;-).

Yes, please forward the email about DOE.

Looks like a good, if not intense (as always), plan. Thanks for doing this!

Jeff

From: Ohrel, Sara
Sent: Thursday, July 03, 2014 1:30 PM
To: Cole, Jefferson
Subject: RE: tasks and schedule - deliberative

Thanks Jeff. Clarification if not clear: this is intended for our (you and me) planning purposes – not the one-pager for Paul. Your comments seem to tend toward something like the one-pager for Paul (which this is not).
- yes, I mean our branch chiefs and chief of staff (SK); figured that might be better than trifecta J
- DOE meeting per the email chain between suzie and I yesterday (you are not on it, I can forward as FYI)
- I was focusing more on AF2 and briefings directly but can mention it.

I included text pertaining to your comment on page 2 in italics but can make it clearer if it helps us organize.

From: Cole, Jefferson
Sent: Thursday, July 03, 2014 1:24 PM
To: Ohrel, Sara
Subject: RE: tasks and schedule - deliberative

Hi Sara,

Thanks for sending this. I've attached my edits. A few quick questions for you:

1. By chiefs are you referring to AF, BI, and SK?
2. Which DOE meeting was this? I do not have this in my notes from our discussion with BI and SK.
3. Should we put our discussion with CAMD on here? This may not be necessary.

Jeff

From: Ohrel, Sara
Sent: Thursday, July 03, 2014 12:50 PM
To: Cole, Jefferson
Subject: tasks and schedule - deliberative

Hi Jeff,
This is what I have so far for our planning purposes – comments welcome

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

Ah – looking at this I am guessing not.
Ok thanks

From: Cole, Jefferson
Sent: Thursday, June 12, 2014 7:20 PM
To: Ohrel, Sara
Subject: compiled comments

Sara,

Here are all of the appendices and SAB response doc combined comments. I've updated the excel file with the current status of these, and you should also be able to find these docs within the folder I shared with you.

In spite of all that, I've attached them all here to make sure you have them on your computer. Here's a tally of what's included, as well as whose comments are in each.

Jeff

SAB Response Doc: OAQPS + OGC
A: OAQPS + OGC
B: *no comments*
C: OAQPS + OTAQ
D: OAQPS only
E: OAQPS only
F: sent earlier today (OAQPS + OGC + OTAQ + TB)
G, H, I: In RTI's hands
J: OAQPS only
K: OAQPS only
L: OAQPS only
M: OAQPS only
N: OAQPS only

_____

Jefferson Cole
Economist
Climate Change Division
U.S. EPA
202.343.9671
cole.jefferson@epa.gov

From:	Ohrel, Sara
To:	Cole, Jefferson
Sent:	7/3/2014 10:29:15 AM
Subject:	FW: Debrief on review of main report text and selected technical appendices
Attachments:	Appendix_F_General Algebraic Representation_5 1_Final edits_TB.docx; Appendix_G_Process Attributes 5 1_Final edits_TB.docx; Appendix_H_Reference Point Landscape Attributes_5 1_Final edits_TB.docx; Appendix_I_Reference Point Baseline Case Studies_5 1_Final edits_TB.docx; Framework_Report_5 1_Final edits_TBv2.docx

Hi Jeff,

Did you incorporate Thomas' comments into the compiled appendices you sent?

Thanks!

From: Thomas Buchholz [mailto:tbuchholz@sig-gis.com]
Sent: Friday, May 30, 2014 1:34 AM
To: Flugge, Mark
Cc: Smith, Eric; Cole, Jefferson; Ohrel, Sara
Subject: Re: Debrief on review of main report text and selected technical appendices

Mark, Eric, Sarah, Jefferson,

Thank you for including me in this round of reviews in the framework, it's great to see how this effort evolved over time. Attached are the framework and appendices with comments and track changes.

In general, I like the structure and the equation as it stands right now with reservations. As a disclaimer, I am traveling right now in East Africa (bioenergy related) and I wish I would have had more time and focus to review this document and particularly more time to make suggestions how to improve it rather than just pointing out potential or real shortcomings.

Below I want to highlight some overarching thoughts I had while reading the materials, I left comments and track changes in the documents as well which provide the core of my review.

Best,
Thomas

Ex. 5 - Deliberative

Ex. 5 - Deliberative

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Thomas Buchholz, PhD, Senior Scientist
Spatial Informatics Group, LLC
3248 Northampton Ct., Pleasanton, CA 94588
cell: +1 802 881 5590, email: tbuchholz@sig-gis.com
```
On 5/29/2014 2:33 PM, Flugge, Mark wrote:

Event Invitation

Title:	Debrief on review of main report text and selected technical appendices
Location:	
When:	Friday, May 30, 2014 9:30 AM – 10:30 AM
Organizer:	Flugge, Mark <Mark.Flugge@icfi.com>
Description:	------------ From: Ohrel, Sara <Ohrel.Sara@epa.gov> Sent: Thursday, May 29, 2014 5:28 PM To: Flugge, Mark; Smith, Eric Cc: Thomas Buchholz (tbuchholz@sig-gis.com) Subject: RE: Technical Direction for ICF 125 - quick turnaround Great, thanks. Yes, anytime during that window works for me. From: Flugge, Mark [mailto:Mark.Flugge@icfi.com] Sent: Thursday, May 29, 2014 5:27 PM To: Smith, Eric; Ohrel, Sara Cc: Thomas Buchholz (tbuchholz@sig-gis.com) Subject: RE: Technical Direction for ICF 125 - quick turnaround Hi Eric: would you and/or Sara be interested in a debrief call with Thomas tomorrow (Friday, May 30) for the biogenic accounting project? Thomas is in Uganda, but could join a call between noon and 2:00 pm our time. Please let me know, and I can circulate a call-in number. Best regards, Mark From: Smith, Eric [mailto:Smith.Eric@epa.gov] Sent: Wednesday, May 28, 2014 4:51

PM To: Flugge, Mark; Ohrel, Sara Cc: Thomas Buchholz (tbuchholz@sig-gis.com<mailto:tbuchholz@sig-gis.com>) Subject: RE: Technical Direction for ICF 125 - quick turnaround Hello Mark and Thomas, Thank you for the note – please simply include the comments in the documents with "track changes." Don't hesitate to let me know if I can be of further assistance. Thanks and regards, Eric Smith Climate Economics Branch Climate Change Division US Environmental Protection Agency 1200 Pennsylvania Ave (6207 J) Washington, DC 20460 (202) 343-9200 (202) 445-6870 alternate location (202) 343-2342 fax From: Flugge, Mark [mailto:Mark.Flugge@icfi.com] Sent: Wednesday, May 28, 2014 4:32 PM To: Smith, Eric; Ohrel, Sara Cc: Thomas Buchholz (tbuchholz@sig-gis.com<mailto:tbuchholz@sig-gis.com>) Subject: RE: Technical Direction for ICF 125 - quick turnaround Hi Eric: we were wondering how you would like to receive comments (e.g., in tracked changes or as a separate document) on the main report and selected technical appendices that Thomas is reviewing? Best regards, Mark From: Smith, Eric [mailto:Smith.Eric@epa.gov] Sent: Wednesday, May 21, 2014 3:41 PM To: Flugge, Mark Cc: Ohrel, Sara Subject: Technical Direction for ICF 125 - quick turnaround Hello Mark, Please arrange for a comprehensive review of the material sent 5/21 by Dr. Thomas Buchholz. Please send him the materials immediately. I will provide a description of the deliverable and a deadline in accordance with the task in a subsequent e-mail tomorrow morning. Thank you and regards, Eric Smith Climate Economics Branch Climate Change Division US Environmental Protection Agency 1200 Pennsylvania Ave (6207 J) Washington, DC 20460 (202) 343-9200(202) 445-6870 alternate location (202) 343-2342 fax _____ From: Flugge, Mark <Mark.Flugge@icfi.com<mailto:Mark.Flugge@icfi.com>> Sent: Wednesday, May 21, 2014 3:10:40 PM To: Smith, Eric Cc: Ohrel, Sara Subject: RE: Technical Direction for ICF 125 - quick turnaround Hi: I heard back from Thomas—he has availability to support this work. Please let me know soonest if you are okay with Thomas starting his review, and I will forward him the documents? He will be traveling to East Africa for a project on May 26, so the earlier he could get the materials, the better; although he anticipates having time to continue going through the materials while traveling. Best regards, Mark From: Flugge, Mark Sent: Wednesday, May 21, 2014 11:42 AM To: 'Smith, Eric' Cc: Ohrel, Sara Subject: RE: Technical Direction for ICF 125 - quick turnaround Hi Eric: regarding an estimated level of effort (LOE) for Thomas Buchholz to provide the work described below during May, I anticipate **Ex. 5 - Deliberative** In the meantime, I am checking in with Thomas to confirm that he is available to support this work. Please see below for a break out based on conservative (i.e., generous assumptions): Assumptions: Ex. 5 - Deliberative

Ex. 5 - Deliberative

communicate main review comments Breakout: Task Task Type Length (pages) LOE (hours) Kick-off Call N/A 1 Appendix F Read 12 1–2 Appendix G Read 22 2–4 AF2 Review 57 14–28 Appendix H Review 25 6–12 Appendix I Review 16 4–8 Appendix F Review 12 3–6 Debrief Call N/A 1–2 Total including review of Appendix F 32–63 Total not including review of Appendix F 29–57 Best regards, Mark MARK FLUGGE | Manager | 202.862.1231 (o) | Mark.Flugge@icfi.com<mailto:Mark.Flugge@icfi.com> | icfi.com<http://www.icfi.com/> ICF INTERNATIONAL | 1725 I Street NW, Suite 1000, Washington, DC 20006 | 202.862.1144 (f) Connect with us on social media<http://www.icfi.com/social>. From: Smith, Eric [mailto:Smith.Eric@epa.gov] Sent: Tuesday, May 20, 2014 1:55 PM To: Flugge, Mark Cc: Ohrel, Sara Subject: Technical Direction for ICF 125 - quick turnaround Hello Mark, Please provide an estimated Level Of Effort for Thomas to review the items listed below. **Ex. 5 - Deliberative**

Ex. 5 - Deliberative

attached. The deliverable for this TD is an e-mail to me and to Sara Ohrel with the estimated LOE. The deadline for this deliverable is noon, tomorrow, May 21. Please contact me or Sara if you should have questions. Thank you and regards, Eric Smith Climate Economics Branch Climate Change Division US

Environmental Protection Agency 1200 Pennsylvania Ave (6207 J) Washington, DC 20460 (202) 343-9200 (202) 445-6870 alternate location (202) 343-2342 fax From: Ohrel, Sara Sent: Tuesday, May 20, 2014 12:25 PM To: Smith, Eric Cc: Cole, Jefferson Subject: Background for ICF 125 Hi Eric, Here is what we would like to include in the TD, requesting Mark to give us a LOE for Thomas to review the items listed below. If the LOE for all components is over the remaining funds available amount, then we can narrow the scope as specified below (i.e., only part of the main doc, 2 reference pt appendices).

Ex. 5 - Deliberative

Ex. 5 - Deliberative Please let me know what else you need from me to move this forward. Thank you! Sara Sara Bushey Ohrel Climate Economics Branch Climate Change Division U.S. Environmental Protection Agency Phone: (202) 343-9712 Cell: (202) 341-6748 --this email is deliberative--do not distribute or cite--

Comment:

	Thomas Buchholz (tbuchholz@sig-gis.com) <tbuchholz@sig-gis.com>
Attendees:	Eric Smith (Smith.Eric@epa.gov) <Smith.Eric@epa.gov>
	Jefferson Cole (Cole.Jefferson@epa.gov) <cole.jefferson@epa.gov>

From:	Ohrel, Sara
To:	Justin Baker (justinbaker@rti.org)
Sent:	6/16/2014 4:55:16 PM
Subject:	BL -deliberative
Attachments:	Black_Liquor_Fate_4-18-14 so.docx

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Bill Irving
CC:	Cole, Jefferson
Sent:	6/16/2014 3:20:35 PM
Subject:	FW: Memo_Default BAF Approach to Biogenic Carbon Regulation
Attachments:	Memo_Default BAF Approach to Biogenic Carbon Regulation.docx

From: Hargrove, Anne
Sent: Monday, June 16, 2014 11:08 AM
To: Fawcett, Allen; Cole, Jefferson; Ohrel, Sara; Irving, Bill; Santiago, Juan; Kornylak, Vera S.; Montanez, Jessica; Dunham, Sarah; Wood, Anna; Kocchi, Suzanne; Mangino, Joseph
Subject: FW: Memo_Default BAF Approach to Biogenic Carbon Regulation

Please see attached memo from NRDC for today's 3 pm meeting. Thanks, Anne Hargrove

Anne Hargrove
Climate Change Division, Management Operations Staff
U.S. Environmental Protection Agency
(202) 343-9926

f - (202) 343-1204

From: Lyutse, Sasha [mailto:slyutse@nrdc.org]
Sent: Friday, June 13, 2014 1:04 PM
To: Gunning, Paul
Cc: Hargrove, Anne
Subject: Memo_Default BAF Approach to Biogenic Carbon Regulation

Hi Paul,

In advance of our meeting on Monday, attached please find a brief memo we've drafted on the potential to use default biogenic accounting factors to determine biogenic carbon emissions from stationary sources. We look forward to discussing next week.

Thanks and have a great weekend,

-Sasha

Sasha Lyutse | Policy Advocate | Natural Resources Defense Council
Office: 310.434.2330 | 1314 Second Street, Santa Monica, CA 90401
slyutse@nrdc.org | www.nrdc.org
Visit my blog on climate, energy & food policy: http://switchboard.nrdc.org/blogs/slyutse/
Follow me on Twitter @SashaLyutse
Follow NRDC's renewables work @NRDCRenewables
Follow NRDC's foodies @NRDCFood

P Please don't print this e-mail unless you need to.
SAVE PAPER. THINK BEFORE PRINTING.

TO: Paul Gunning, Sarah Dunham EPA
FR: Sami Yassa, Nathanael Greene, Sasha Lyutse, NRDC
RE: Default BAF Approach to Biogenic Carbon Regulation
DT: June 12, 2014

Overview

In advance of our meeting on Monday, June 16, this memo briefly outlines NRDC's thoughts on an analytic approach for determining biogenic carbon emissions from stationary sources based on "default Biogenic Accounting Factors" (BAFs). Under this approach, EPA would adjust an individual facility's stack emissions to account for future sequestration and/or avoided emissions using a BAF specific to the feedstock(s) used. The factor would be generic and generally applicable to all covered facilities in a given region - thus avoiding the need to carry out facility-by-facility modeling and analysis.

This approach originated in the SAB's final report to the EPA, *Scientific Advisory Board Review of EPA's Accounting Framework for Biogenic CO2 Emissions from Stationary Sources* (September 2011):

> Default BAFs for each category of feedstocks would differentiate among feedstocks using general information on their role in the carbon cycle. An anticipated baseline would allow for consideration of prior land use, management, alternate fate (what would happen to the feedstock if not combusted for energy) and regional differences. Default BAFs might vary by region, prior land use and current land management practices due to differences these might cause in the interaction between feedstock production and the carbon cycle.

This recommendation addresses several key scientific factors that are essential to accurate biogenic accounting. We believe that it warrants serious attention by EPA as it develops a framework for regulating biogenic carbon. Specifically, this approach:

- applies to individual facilities instead of using flawed regional reference point baselines;
- differentiates among different forest-derived fuel types;
- employs an anticipated future baseline (i.e. business as usual) that correctly accounts for additional emissions from feedstock combustion;
- provides regional specificity;
- accounts for key factors including land use, management approaches, end uses, alternate fates;
- relies on "readily-available" information and data, such as growth/mortality, decay rates, climatic variables and customary silviculture.

Modeling and Applying Default BAFs

The BAF is defined as the ratio of Net Biogenic Emissions and Gross Emissions. Since the net change in carbon stores in the system from which the biomass is removed is a measure of the net biogenic emissions from that system (ignoring other inputs to/outputs from the system), then

BAF = Net change in stored carbon / Biogenic C released by burning

The BAF is dimensionless number that defines how much of the carbon released from an individual biomass facility is not recycled back into the terrestrial ecosystem. Because the burning and the recycling happen over time, the BAF is a time-dependent. A BAF equal to one means that all carbon removed from the ecosystem is lost to the atmosphere. A BAF of zero means carbon neutrality (harvest does not change carbon stores over time).

This BAF default approach has three key features:

1. This approach uses a baseline capable of capturing additional emissions from feedstock combustion. Under this approach, the modeling of changes in stored carbon relies on an anticipated future baseline—i.e. comparing emissions from increased biomass harvesting against a "business as usual" baseline to a scenario absent increased biomass demand for bioenergy. In other words, the net change in stored carbon would be the difference between two cases: when the current system of management (silviculture and end uses) is continued versus the new management system in which biogenic harvests are occurring for new bioenergy uses. The model(s) used to determine net changes in carbon should not be limited to silviculture and related activities, but should likewise address end uses, market driven shifts, and alternate fates as well.

2. This approach is best applied to long-carbon-accumulation feedstocks (what the SAB referred to as "long-recovery feedstocks"), especially those derived from forests. First, EPA would identify categories of feedstocks and would identify major regions of analysis. For each region, modeling would determine the net change in stored carbon that results from the removal and combustion of a particular feedstock (the numerator in the BAF). Knowing this net change in stored carbon, the agency would calculate the BAF for each feedstock in each region, producing a "lookup table" with default numbers to apply to stack emissions based on a covered facility's mix of feedstocks.

3. Default BAFs can be calculated over a timeframe relevant to reducing greenhouse gas emissions in line with EPA's climate goals. Because the BAF is a factor that varies over time, its applied value will depend on the policy timeframe chosen. In our judgment, near-term timeframes are the most important for climate policies. The running average BAF would capture the cumulative effect of sequestration at a chosen year relevant to such policy timeframes.

4. There may be certain feedstocks that intrinsically have a BAF of near zero or one. True wastes that would otherwise quickly decompose and release the biogenic carbon to the atmosphere would be near zero. Conversely whole trees from protected forests not prone to forest-fires would be an obvious example of a feedstock that would be intrinsically one.

- Ncasi regions
- Justification for exempting residuals; please consider the science and technical elements discussed in section II (the rest are more about specific permitting and legal components)
- Ncasi mfg residuals study (oct 2013) and Nov 23 summary of changes to report
- Baf report regions
- Just FYI - Biogenic carbon accounting paper

For the above, please identify

Ex. 5 - Deliberative

Ex. 5 - Deliberative

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute, discuss, cite

An Approach to Using FIA Data in Calculations of Biogenic Accounting Factors for 4 US Regions

National Council for Air and Stream Improvement [*]

March 7, 2014

Background

EPA plans to release a new version of its accounting framework for biogenic CO2 emissions from stationary sources during the first half of 2014. It is expected that the new framework will include a procedure for calculating Biogenic Accounting Factors (BAFs) that is based, in part, on forest conditions in regions of the United States.

In EPA's 2011 draft accounting framework, BAF is defined as: "The fraction of Potential Gross Emissions that becomes a net biogenic CO2 emission to the atmosphere from using a biologically based feedstock, taking into consideration growth and emission avoidance, carbon stored in products, and site sequestration effects." Important aspects of BAF calculation procedures in the draft 2011 framework included (i) consideration of forest conditions in regions from which stationary sources of biogenic CO2 obtain biomass feedstock; and (ii) designation of CO2 emissions from some kinds of feedstock as "anyway emissions" that make zero contribution to net biogenic emissions.

This document describes a simple and practical approach for considering forest conditions in BAF calculations. The central concept is to use data from the public USDA Forest Service Forest Inventory and Analysis Program (FIA)[1] to calculate estimates of above-ground forest biomass (AGB) for a baseline period and for an assessment period for each of several regions in the United States. If the assessment period AGB is not

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[*]http://www.ncasi.org/
[1]FIA database downloaded on March 1, 2014

1

significantly less than the baseline period AGB, then BAF=0 for that region. If the assessment period AGB is significantly less than baseline period AGB, further analysis could be undertaken to determine whether an increasing rate of timber harvest for bioenergy accounts for the difference in AGB between the baseline and assessment periods.

Methods

We are suggesting FIA data be used to compute estimates of AGB, because it is publicly available and relatively consistent for the lower 48 states. In the example below, we produce estimates of AGB in 4 analysis regions (Fig 1).

- North: CT, DL, IL, IN, IA, KS, MA, ME, MD, MI, MN, MO, NE, NH, NJ, NY, ND, OH, PA, RI, SD, VT, WV, WI

- South: AL, AR, FL, GA, KY, LA, NC, OK, SC, MS, TN, TX, VA

- SouthWest: AZ, CO, NV, NM, UT

- PacifCoastNW: CA, OR, WA, ID, MT
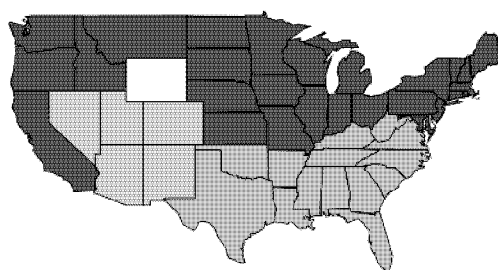
Figure 1: Analysis regions

FIA does not yet have sufficient annual inventory data for WY for that state to be included in the analysis. FIA data for AK is generally limited to coastal areas and was not included. We have not yet considered HI.

For this analysis, we are interested in estimates of AGB (tons) per acre on four classes of forestland defined by owner group and potential for timber production: private timberland; private non-timberland; public timberland; and public non-timberland. The private owner group includes all private owners (individuals, families, corporations, etc). The public owner group includes units of government at all levels (local, county, state, tribal, and federal). Timberland (TL) is defined by FIA as forestland that is not administratively reserved and can grow at least 20 ft^3 per acre annually. Non-timberland (NTL) is forestland that does meet the definition of timberland because it is reserved from timber production and/or has low productivity.

Annual estimates of AGB or each region were computed for four classes of forestland by averaging plot-level estimates of AGB over a moving window of years. The wider the window, the less variable the result and the less sensitive it is to short term trends. The results for 1, 3 and 5 year windows for four classes of forestland are shown in tables in the Appendix. For example, the result for 2010 is the mean of plots measured in 2010 for a 1 year window, for the 3 year window it includes plots from 2009-2011, and for the 5 year window it includes plots from 2008-2012. Increasing the window width will decrease the length of the trend that can be estimated.

Per acre above ground biomass
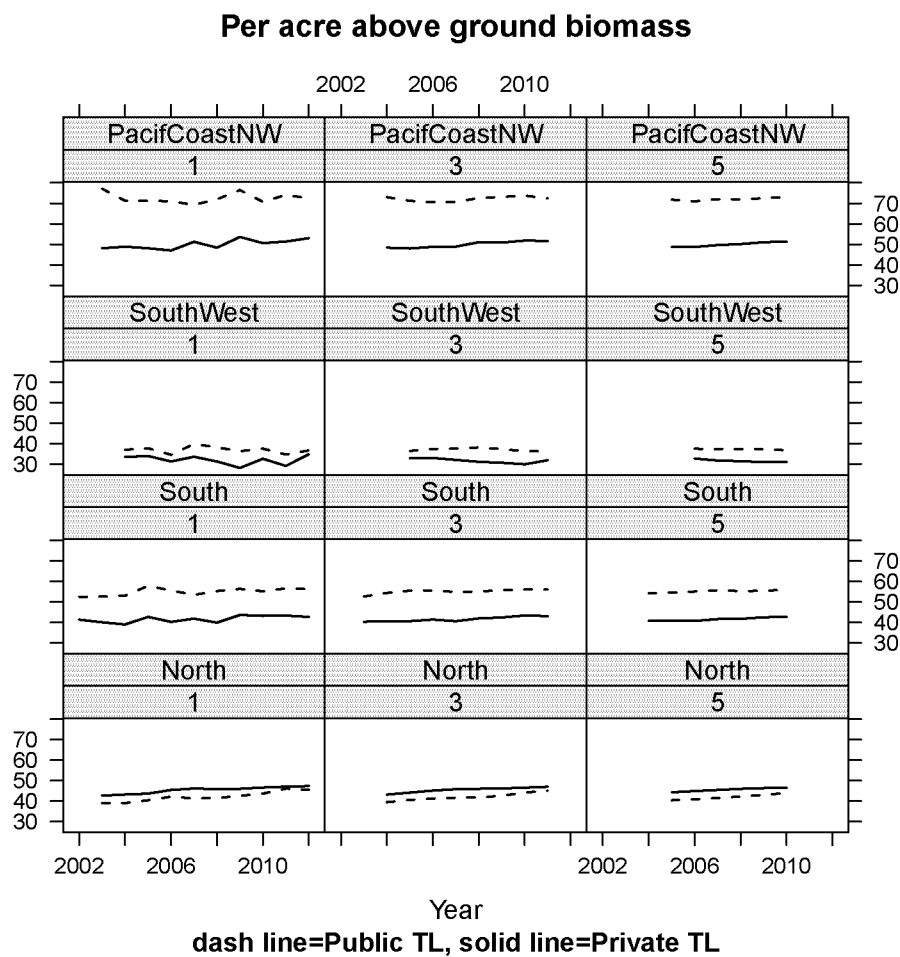
Figure 2: Per acre above ground biomass trends for moving windows of widths 1, 3 and 5 years shown by region for public and private timberland.

Years were excluded where less than 75% of the states in the region had measurements. Figure (2) shows trends for public and private timberland by window width and region. Figure (2) makes several points:

1. Variability of the estimated trend decreases with increasing window width

2. Trends in AGB are generally flat with slight increases or decreases over time. Trends on private lands are positive (increasing) except in the SouthWest.

3. Increasing window width reduces the number of available annual estimates

4. Per acre means vary by region and owner

Several considerations justify using timberland AGB per acre values when analyzing forest conditions in support of BAF calculations: (i) Estimates of change in forest area are much more uncertain than estimates of change in AGB per acre; (ii) Losses of forest area are typically due to development or agricultural expansion, not changes in forest harvest rates; and (iii) Changes in harvest rate are more likely to affect AGB on timberland than on non-timberland that is reserved or unproductive.

Viewing trends in per acre AGB (Fig 2) is useful, but it does not provide a simple BAF statistic. We split the span of years where sufficient data are available into 2 periods for each region, i.e. a baseline period followed by an assessment period. Our approach was to assign an equal number of years to each period with the baseline period getting the extra year when the total number of years is odd. We used a one-sided two-sample t-test assuming unequal variances and independent samples to test Ho: assessment=baseline versus the alternative that the difference in means (assessment-baseline) is less than 0. Large p-values suggest that Ho cannot be rejected. A small p-value (say <0.025) suggests that the assessment period mean AGB is less than the baseline period AGB when the t-value is negative.

The t-test results (Tab 1) indicate that the baseline and the assessment periods are significantly different for all regions. However, the regions with negative t-values (except in the SouthWest) show a decline in AGB for the assessment period for some owner groups.

	Region	Owner	Years	Estimates	p-value	t-value	df
1	North	Private TL	2003,2007,2012	44.72,46.62	0	1122.99	44604
2	North	Public TL	2003,2007,2012	40.8,44.01	0	767.43	19099
3	South	Private TL	2002,2007,2012	40.71,42.69	0	1289.3	53060
4	South	Public TL	2002,2007,2012	54.51,56.15	0	138.94	7814
5	SouthWest	Private TL	2004,2008,2012	32.57,31.04	0	-14.81	625
6	SouthWest	Public TL	2004,2008,2012	37.6,36.36	0	-38.83	2215
7	PacifCoastNW	Private TL	2003,2007,2012	48.79,51.37	0	84.35	4414
8	PacifCoastNW	Public TL	2003,2007,2012	70.7,73.15	0	165.26	13043

Table 1: One-sided two-sample t-test assuming independent samples with unequal variances. Satterthwaite's approximation is used to compute degrees of freedom (df). Results are shown for timberland (TL) by region and owner. The Years column gives the beginning and end of the baseline period and the end of the assessment period. The estimates are the baseline and assessment period means. The p value is based on the computed t-value and df. The magnitude of the t-value indicates the effect size.

Appendix

Tables (2) - (4) show per acre above ground biomass, with sample size in parentheses for moving windows of 1, 3 and 5 years, based on FIA plots from the current inventory year for states: CT, DL, IL, IN, IA, KS, MA, ME, MD, MI, MN, MO, NE, NH, NJ, NY, ND, OH, PA, RI, SD, VT, WV, WI

	Private NTL	Private TL	Public NTL	Public TL	All
2003	25.82 (54)	42.72 (5226)	48.49 (306)	38.97 (2267)	41.75 (7853)
2004	16.53 (53)	43.26 (5038)	46.87 (252)	39.07 (2160)	41.99 (7503)
2005	22.03 (58)	43.69 (5065)	44.04 (227)	40.46 (2270)	42.58 (7620)
2006	18.16 (54)	45.47 (5654)	51.69 (285)	42.2 (2316)	44.59 (8309)
2007	15.39 (77)	46.18 (5737)	48.68 (326)	41.33 (2368)	44.65 (8507)
2008	19.03 (51)	45.92 (4690)	53.85 (260)	41.51 (1840)	44.83 (6841)
2009	19.61 (57)	46.05 (4849)	52.48 (263)	42.6 (1878)	45.16 (7047)
2010	21.04 (43)	46.67 (4738)	51.97 (237)	43.7 (2089)	45.82 (7108)
2011	20.26 (52)	47.09 (4704)	56.86 (284)	46.14 (2141)	47 (7181)
2012	22.87 (66)	47.36 (4747)	51.87 (316)	45.54 (2200)	46.79 (7329)

Table 2: Per-acre above-ground biomass and sample size based on a 1 year moving window for the North region

	Private NTL	Private TL	Public NTL	Public TL	All
2004	21.5 (164)	43.22 (15330)	46.68 (785)	39.51 (6697)	42.1 (22976)
2005	18.99 (165)	44.19 (15757)	47.83 (765)	40.61 (6746)	43.1 (23433)
2006	18.21 (189)	45.17 (16456)	48.45 (838)	41.33 (6954)	43.98 (24437)
2007	17.23 (182)	45.85 (16081)	51.21 (871)	41.69 (6524)	44.68 (23658)
2008	17.69 (185)	46.06 (15277)	51.44 (849)	41.78 (6086)	44.86 (22396)
2009	19.83 (151)	46.21 (14277)	52.79 (761)	42.65 (5807)	45.27 (20996)
2010	20.24 (153)	46.6 (14291)	53.91 (785)	44.22 (6107)	46 (21336)
2011	21.53 (161)	47.04 (14189)	53.59 (838)	45.14 (6430)	46.54 (21618)

Table 3: Per-acre above-ground biomass and sample size based on a 3 year moving window for the North region

	Private NTL	Private TL	Public NTL	Public TL	All
2005	19.29 (295)	44.33 (26720)	48.17 (1396)	40.43 (11381)	43.17 (39793)
2006	18.05 (292)	44.94 (26184)	49.19 (1351)	40.92 (10954)	43.75 (38781)
2007	18.62 (297)	45.47 (25996)	50.26 (1361)	41.59 (10672)	44.35 (38326)
2008	18.3 (282)	46.04 (25668)	51.59 (1372)	42.25 (10491)	44.98 (37813)
2009	18.69 (281)	46.37 (24718)	52.66 (1370)	43.07 (10316)	45.47 (36685)
2010	20.65 (269)	46.62 (23728)	53.43 (1361)	44.01 (10148)	45.94 (35507)

Table 4: Per-acre above-ground biomass and sample size based on a 5 year moving window for the North region

Tables (5) - (7) show per acre above ground biomass, with sample size in parentheses for moving windows of 1, 3 and 5 years, based on FIA plots from the current inventory year for states: AL, AR, FL, GA, KY, LA, NC, OK, SC, MS, TN, TX, VA

	Private NTL	Private TL	Public NTL	Public TL	All
2002	12.97 (13)	41.34 (7527)	62.06 (155)	52.53 (1210)	43.18 (8905)
2003	9.49 (13)	40.06 (5129)	52.12 (104)	52.54 (743)	41.75 (5989)
2004	6.97 (656)	38.99 (4623)	38.94 (98)	53 (664)	37.05 (6041)
2005	7.68 (590)	42.7 (4894)	42.85 (100)	57.83 (650)	40.96 (6233)
2006	7.14 (581)	40.25 (7538)	36.56 (125)	55.56 (1038)	39.84 (9282)
2007	7.92 (564)	41.82 (4609)	43.68 (158)	53.44 (728)	40.11 (6059)
2008	8.53 (692)	39.9 (4409)	40.17 (111)	55.27 (621)	37.82 (5833)
2009	7.01 (692)	43.64 (5679)	42.32 (187)	56.36 (901)	41.75 (7459)
2010	8.6 (733)	43.17 (5394)	43.2 (141)	55.17 (835)	41.02 (7103)
2011	6.85 (818)	43.33 (5538)	40.46 (170)	56.58 (854)	40.76 (7380)
2012	12.14 (108)	42.66 (4954)	47.63 (123)	56.24 (758)	43.94 (5942)

Table 5: Per-acre above-ground biomass and sample size based on a 1 year moving window for the South region

	Private NTL	Private TL	Public NTL	Public TL	All
2003	7.14 (682)	40.33 (17279)	52.82 (357)	52.65 (2616)	41 (20935)
2004	7.33 (1259)	40.6 (14647)	44.78 (302)	54.36 (2056)	39.93 (18263)
2005	7.26 (1827)	40.61 (17056)	39.23 (323)	55.47 (2352)	39.38 (21557)
2006	7.58 (1734)	41.38 (17041)	41.14 (383)	55.53 (2416)	40.24 (21574)
2007	7.91 (1836)	40.59 (16556)	40.44 (394)	54.84 (2388)	39.36 (21174)
2008	7.82 (1948)	41.95 (14697)	42.27 (456)	55.12 (2250)	40.05 (19351)
2009	8.06 (2117)	42.41 (15482)	42.06 (438)	55.65 (2357)	40.37 (20395)
2010	7.47 (2243)	43.39 (16611)	41.93 (498)	56.05 (2590)	41.18 (21942)
2011	7.97 (1658)	43.07 (15886)	43.38 (434)	55.99 (2447)	41.77 (20424)

Table 6: Per-acre above-ground biomass and sample size based on a 3 year moving window for the South region

	Private NTL	Private TL	Public NTL	Public TL	All
2004	7.31 (1853)	40.7 (29712)	47.62 (582)	54.14 (4304)	40.7 (36450)
2005	7.42 (2403)	40.71 (26794)	42.72 (585)	54.51 (3823)	39.94 (33604)
2006	7.66 (3082)	40.7 (26073)	40.6 (592)	55.04 (3701)	39.24 (33448)
2007	7.66 (3118)	41.61 (27129)	41.31 (681)	55.68 (3939)	40.16 (34867)
2008	7.87 (3261)	41.72 (27629)	41.46 (722)	55.24 (4123)	40.19 (35736)
2009	7.75 (3498)	42.51 (25629)	42.04 (767)	55.44 (3939)	40.41 (33834)
2010	7.88 (3043)	42.66 (25974)	42.62 (731)	55.96 (3969)	41.08 (33717)

Table 7: Per-acre above-ground biomass and sample size based on a 5 year moving window for the South region

Tables (8) - (10) show per acre above ground biomass, with sample size in parentheses for moving windows of 1, 3 and 5 years, based on FIA plots from the current inventory year for states: AZ, CO, NV, NM, UT

	Private NTL	Private TL	Public NTL	Public TL	All
2004	10.3 (186)	33.47 (54)	13.05 (650)	36.98 (245)	18.74 (1135)
2005	9.07 (308)	33.97 (87)	12.34 (870)	37.78 (279)	17.51 (1544)
2006	10.15 (326)	31.31 (82)	13.43 (835)	34.53 (274)	17.5 (1517)
2007	10.15 (326)	33.58 (84)	12.39 (815)	39.88 (273)	18.09 (1497)
2008	8.78 (316)	31.29 (81)	12.48 (792)	38.18 (280)	17.63 (1468)
2009	10.04 (329)	28.14 (74)	11.96 (831)	36.32 (269)	16.7 (1503)
2010	9.52 (345)	32.63 (71)	11.91 (838)	37.54 (286)	17.09 (1540)
2011	9.96 (303)	29.12 (77)	12.13 (839)	34.71 (267)	16.63 (1485)
2012	9.17 (290)	34.77 (57)	12.22 (828)	36.68 (269)	17.05 (1444)

Table 8: Per-acre above-ground biomass and sample size based on a 1 year moving window for the SouthWest region

	Private NTL	Private TL	Public NTL	Public TL	All
2005	9.78 (820)	32.87 (223)	12.92 (2355)	36.42 (798)	17.84 (4196)
2006	9.8 (959)	32.98 (252)	12.72 (2521)	37.4 (826)	17.7 (4559)
2007	9.7 (967)	32.07 (246)	12.78 (2442)	37.53 (827)	17.74 (4483)
2008	9.66 (970)	31.11 (238)	12.27 (2437)	38.14 (822)	17.47 (4469)
2009	9.45 (990)	30.68 (226)	12.11 (2460)	37.36 (835)	17.13 (4511)
2010	9.83 (977)	29.92 (222)	12 (2507)	36.22 (822)	16.81 (4528)
2011	9.55 (939)	31.91 (205)	12.09 (2504)	36.34 (822)	16.92 (4469)

Table 9: Per-acre above-ground biomass and sample size based on a 3 year moving window for the SouthWest region

	Private NTL	Private TL	Public NTL	Public TL	All
2006	9.65 (1461)	32.7 (387)	12.73 (3962)	37.49 (1351)	17.85 (7162)
2007	9.65 (1604)	31.76 (407)	12.52 (4143)	37.35 (1375)	17.48 (7530)
2008	9.73 (1642)	31.43 (391)	12.43 (4111)	37.3 (1382)	17.4 (7526)
2009	9.69 (1619)	30.99 (386)	12.17 (4114)	37.35 (1375)	17.22 (7494)
2010	9.5 (1583)	30.99 (360)	12.14 (4126)	36.71 (1371)	17.02 (7440)

Table 10: Per-acre above-ground biomass and sample size based on a 5 year moving window for the SouthWest region

Tables (11) - (13) show per acre above ground biomass, with sample size in parentheses for moving windows of 1, 3 and 5 years, based on FIA plots from the current inventory year for states: CA, OR, WA, ID, MT

	Private NTL	Private TL	Public NTL	Public TL	All
2003	19.94 (118)	48.08 (479)	55.62 (433)	77.11 (1312)	64.31 (2343)
2004	18.3 (113)	48.84 (553)	52.73 (503)	71.26 (1556)	61.09 (2725)
2005	25.55 (117)	48.09 (521)	52.63 (527)	71.34 (1600)	61.46 (2765)
2006	26.57 (115)	46.98 (539)	52.92 (508)	70.94 (1526)	60.84 (2688)
2007	23.08 (124)	51.24 (535)	49.58 (553)	69.26 (1591)	59.9 (2803)
2008	23.08 (119)	48.35 (522)	51.44 (520)	71.98 (1479)	61.06 (2640)
2009	23.7 (106)	53.6 (510)	50.79 (504)	76.46 (1568)	65.24 (2687)
2010	22.81 (116)	50.58 (535)	55.53 (478)	70.74 (1538)	61.89 (2667)
2011	23.29 (105)	51.37 (544)	55.61 (469)	74.06 (1489)	63.96 (2607)
2012	19.38 (104)	53 (541)	57.85 (433)	72.44 (1584)	64.05 (2661)

Table 11: Per-acre above-ground biomass and sample size based on a 1 year moving window for the PacifCoastNW region

	Private NTL	Private TL	Public NTL	Public TL	All
2004	21.29 (348)	48.36 (1553)	53.55 (1464)	73.01 (4468)	62.18 (7833)
2005	23.51 (345)	47.98 (1612)	52.76 (1538)	71.18 (4683)	61.13 (8178)
2006	25.02 (355)	48.77 (1594)	51.66 (1588)	70.51 (4718)	60.73 (8256)
2007	24.2 (358)	48.86 (1596)	51.26 (1581)	70.69 (4596)	60.58 (8130)
2008	23.27 (349)	51.04 (1567)	50.58 (1577)	72.56 (4638)	62.04 (8130)
2009	23.18 (340)	50.82 (1567)	52.53 (1502)	73.1 (4585)	62.74 (7994)
2010	23.25 (327)	51.82 (1589)	53.91 (1451)	73.77 (4595)	63.69 (7962)
2011	21.87 (325)	51.65 (1621)	56.28 (1380)	72.4 (4611)	63.29 (7936)

Table 12: Per-acre above-ground biomass and sample size based on a 3 year moving window for the PacifCoastNW region

	Private NTL	Private TL	Public NTL	Public TL	All
2005	22.7 (587)	48.66 (2626)	52.55 (2525)	71.8 (7586)	61.43 (13324)
2006	23.33 (588)	48.7 (2669)	51.82 (2611)	70.94 (7753)	60.86 (13621)
2007	24.38 (580)	49.62 (2626)	51.45 (2612)	71.99 (7764)	61.68 (13582)
2008	23.83 (579)	50.12 (2640)	51.97 (2563)	71.88 (7702)	61.77 (13485)
2009	23.18 (570)	51.02 (2646)	52.45 (2524)	72.49 (7665)	62.38 (13404)
2010	22.48 (550)	51.37 (2653)	54.08 (2403)	73.15 (7657)	63.24 (13263)

Table 13: Per-acre above-ground biomass and sample size based on a 5 year moving window for the PacifCoastNW region

The Case for Excluding CO_2 Emissions from Burning Forest Products Manufacturing Residuals for Energy Recovery from PSD Permitting and BACT Requirements

April 2014

EXECUTIVE SUMMARY

A different regulatory approach for biogenic carbon dioxide (CO_2) supports our national policy goals to reduce greenhouse gas (GHG) emissions and the use of fossil fuels. There are strong scientific and policy reasons for EPA to differentiate, in its Prevention of Significant Deterioration (PSD) permitting regulations, between burning biomass for energy recovery and burning fossil fuels. The Clean Air Act and established principles of administrative law give EPA discretion to do so. EPA already has made many analogous distinctions in the PSD program, often with explicit support from the courts. The scientific and legal rationale and impetus are particularly strong for EPA to exclude CO_2 emissions from the burning of forest products manufacturing residuals and other similar materials from PSD review, because such use results in less GHGs in the atmosphere than if those materials were not burned for energy recovery.

Emissions from Burning Biomass Contain Carbon Already Circulating in the Natural Carbon Cycle and Thus Do Not Contribute to the Build-up of Greenhouse Gases in the Atmosphere.

The burning of biomass for energy recovery, unlike the burning of fossil fuel, does not contribute to the "air pollution" that EPA has identified as its purpose for regulating GHG emissions, namely, the net flow of carbon into the global atmosphere from terrestrial carbon stocks, resulting in an undesirable build-up of GHGs in the Earth's atmosphere. That is because CO_2 emissions from biomass combustion are part of a natural carbon cycle. The carbon that forms CO_2 when biomass is burned was previously removed from the atmosphere when that biomass was created through the photosynthesis of plant matter from CO_2 the plant absorbed from the air. Likewise, the CO_2 emitted when the biomass is burned contributes to atmospheric stocks from which CO_2 will be removed by new plant growth. So long as biomass growth is exceeding the amount harvested, burning of biomass as part of that carbon cycle is not contributing to the build-up of GHGs in the global atmosphere that EPA is attempting to address with CAA permitting.

Burning biomass for energy recovery therefore is fundamentally different from burning fossil fuels. In the latter case, carbon is being removed from geological stocks and transferred to the atmosphere, something that would not occur but for extraction and combustion of the fossil fuel. By the same token, the geological stock of carbon is not, and cannot be, renewed in conjunction with burning fossil fuels, in contrast to biomass-based fuels, where harvested biomass is being replaced with new growth. EPA and many other environmental authorities have recognized that using biomass for energy instead of fossil fuel therefore mitigates the build-up of GHGs in the global atmosphere.

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Removing Barriers to Bioenergy Furthers the Goals of the Clean Air Act and Energy Policy.

As the courts have emphasized, EPA, in interpreting the scope of the PSD program, must consider Congress's two primary goals in enacting the PSD provisions of the Clean Air Act (CAA): protecting and improving air quality, and not interfering unduly with business investment in the productive capacity of the nation. Categorically excluding CO_2 emissions from combustion of biomass for energy recovery from Prevention of Significant Deterioration (PSD) permitting requirements would be consistent with both goals. It would also support important energy policy goals, which EPA has discretion to consider in interpreting the scope of the PSD provisions of the CAA.

Because CO_2 emissions from combustion of biomass for energy recovery do not contribute to the build-up of GHGs in the atmosphere, subjecting those emissions to PSD permitting requirements does not further the regulatory goal of reducing the "air pollution" that EPA is attempting to address through PSD permitting of GHG emissions. Moreover, imposing PSD permit requirements would create a disincentive for the use of biomass-based fuels rather than fossil fuels. Due to the generally higher heat value of fossil fuel versus biomass, higher moisture content of biomass burned for energy recovery, and other factors, fossil-fuel burning typically will emit less CO_2 than biomass burning to achieve the same heat output (although, unlike emissions from fossil fuel use, the CO_2 from burning biomass for energy is not contributing to the build-up of GHGs in the global atmosphere). Because of this CO_2 emission rate difference, if the two are treated the same for PSD purposes, facilities could have an incentive to stay with or choose fossil fuel to meet a project's incremental energy needs, instead of biomass, so as to avoid triggering PSD permitting or a lengthy and uncertain Best Available Control Technology (BACT) demonstration for GHGs. As a result, there would be increased transfer of geologic carbon to the atmosphere, rather than reducing that input.

In its Tailoring Rule, as well as in its rule temporarily deferring application of PSD permitting to biogenic CO_2 emissions, EPA acknowledged the substantial additional effort imposed on both permit applicants and permitting authorities if a PSD permit, including novel determinations of BACT, were required for GHG emissions, and for biogenic CO_2 emissions in particular. As EPA is aware, there are a substantial number of new projects firing biomass-based fuels that are pending or have been constructed recently that would only require a PSD permit if biogenic CO_2 emissions triggered PSD applicability. Applying for and obtaining a PSD permit can impose a delay of a year or more, as well as significantly increasing the uncertainty about when, or even whether, a project can be constructed, and at what cost. At best, subjecting biomass-fired projects to PSD permitting would substantially delay the benefits of substituting biogenic CO_2 emissions for fossil-fuel CO_2 emissions, and at worst it could make financing some of those projects infeasible. In addition, anything that increases the difficulty and cost of constructing and operating equipment fired with woody biomass reduces the value of timber, reducing the incentive for landowners to maintain and increase forest stocks (and their associated carbon sequestration).

Excluding CO_2 emissions from combustion of biomass for energy recovery from PSD permitting also would further important energy policy goals. Pre-construction permitting requirements that discourage use of biomass-based fuels or that impose substantial delays on new biomass projects are contrary to the strong national goals of increasing use of renewable energy, reducing reliance on unstable foreign energy supplies, reducing the balance of payments,

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etc. Excluding CO_2 emissions from use of biomass as fuel from PSD requirements would remove a substantial impediment to construction of new biomass-fired units (while avoiding the irrational incentive for using fossil fuel over biomass that exists if CO_2 emissions from using biomass as fuel are weighted the same as fossil-fuel CO_2 emissions for PSD and BACT applicability purposes).

Using Forest Products Manufacturing Residuals for Energy Avoids GHG Emissions from their Alternative Fate.

The reasons for a categorical exclusion for CO_2 emissions from burning biomass for energy recovery are particularly strong and unique in the case of residuals generated in the manufacture of pulp, paper, wood products, lumber, and other forest products. Unlike other activities that EPA has regulated under the PSD program up to now, burning forest products manufacturing residuals for energy recovery has the effect of reducing GHG emissions that would have occurred if the residuals were managed as wastes, i.e. their alternative fate. For example, massive quantities of bark residuals are generated when the bark is removed from logs in the process of manufacturing pulp and paper. If not burned for energy recovery, it still has to be disposed of in some way. Landfilling of bark will, over a short time, generate GHG emissions with greater global warming potential than the GHG emissions generated by burning the bark for energy recovery.[1] An analysis by the National Council for Air and Stream Improvement demonstrates that such "anyway emissions" either equal or are greater than emissions from use as fuel, from a global warming perspective, for all forest products manufacturing residuals. On average, the global warming effect of <u>not</u> burning forest products residuals for energy recovery exceeds the global warming effect of using the residuals as fuel in just 2.4 years.

This favorable effect arising from the burning of forest products manufacturing residuals, which are unavoidably generated in the manufacture of various commercial products and would otherwise have to be disposed of, does not include considering the benefit of substituting biogenic CO_2 emissions for CO_2 emissions from fossil fuels. As discussed above, if fossil fuels are used instead of forest products manufacturing residuals to meet energy needs, that use transfers carbon stocks from geological formations to the atmosphere. Similar considerations apply to numerous other types of activities, such as using biogas from the digestion of municipal wastewater treatment plant sludge as a fuel, where there otherwise would be "anyway emissions" equal to or exceeding the global warming potential of emissions associated with burning the material for energy recovery. Thus, burning forest products manufacturing residuals and various other biomass residuals for energy recovery does not contribute to the air pollution that EPA seeks to address by including GHGs in the PSD program, and discouraging the use of such residuals as fuel is counterproductive for achieving the goal of reducing build-up of GHGs in the global atmosphere (as well as for national energy policy goals). EPA cannot reasonably ignore this scientific reality.

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[1] A small fraction of the bark generated by pulp and paper manufacturing can be used in landscape products, but the vast majority must be either landfilled or used as a fuel. Even if used in landscape products, over a short period of time much of the carbon will be emitted to the atmosphere as CO_2 and, under some circumstances, as methane. Other residuals generated in large quantities at pulp and paper mills, such as black liquor and wastewater treatment plant sludge, have no commercially feasible alternative uses even for a fraction of the amount generated.

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EPA Has the Legal Authority and Discretion To Differentiate Between Burning Biomass for Energy Recovery and Burning Fossil Fuels.

Fortunately, the discretion that EPA has in interpreting the Clean Air Act's PSD provisions, both inherent in the statutory scheme and resulting from application of settled principles of administrative law, allows EPA to further the purposes of the Act and other important national policy goals by differentiating between burning biomass for energy recovery and burning fossil fuels.

The courts have consistently found that the terms Congress used to delineate the PSD program are broad enough to give EPA substantial discretion in fashioning a PSD program that furthers the dual goals of protecting air quality and not unnecessarily impeding industrial development.[2] For example, the Supreme Court has held that EPA can interpret "stationary source" to be an entire plant for PSD purposes but an individual piece of equipment for nonattainment new source review purposes (*Chevron*) and can interpret "modification" to mean one thing for PSD and another for New Source Performance Standards (*Duke Energy*). EPA has interpreted "modification" in the PSD regulations to exclude (often with judicial approval) such things as routine maintenance, repair, and replacement; switching to another fuel; increasing hours of operation; and changes that do not result in an increase above a Plantwide Applicability Limit.

Of particular relevance for treatment of the burning of biomass for energy recovery is EPA's exclusion, with the support of the D.C. Circuit *Alabama Power* decision, from PSD permitting as a "modification" any change that does not result in increased emissions above specified "significance levels" (which can be as high as the "major stationary source threshold itself"). EPA's discretion in interpreting the CAA provisions allowed it, in that instance, to exclude activities where there would be little or no regulatory benefit from including such "trivial" emissions (the *de minimis* principle). Similarly, EPA's decision to limit PSD permitting requirements to any pollutant regulated under the CAA, although the statutory language contains no such limitation, was within EPA's discretion to limit the PSD program to what it thought Congress intended to cover, according to the D.C. Circuit's *Coalition for Responsible Regulation* decision (reviewing the Tailoring Rule). There the Court held it would be "absurd" to think Congress intended to require PSD permitting for emissions that have not been found to endanger health and welfare, following a long line of Supreme Court cases giving agencies leeway to depart from a literal application of statutory requirements when to do so would produce absurd results or be inconsistent with the purposes of the statute.

These and other judicial precedents fit neatly with the facts described above: EPA could and should determine that Congress did not intend to subject projects to PSD permitting requirements, including a BACT demonstration, based on the project's emissions of biogenic CO_2 that, as part of the carbon cycle, do not cause the air pollution that EPA is seeking to regulate – accumulation of GHGs in the global atmosphere. Moreover, it would be inconsistent with congressional goals to inhibit use of biomass to satisfy energy demands. It is particularly

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[2] In 2013, the D.C. Circuit concluded that EPA had not provided sufficient justification for a rule excluding all biogenic CO_2 emissions from PSD permitting for three years while EPA studies how to regulate biogenic emissions. *Center for Biological Diversity v. EPA*, 722 F.3d 401. Both the majority opinion and the dissent, however, recognized that there are a number of ways EPA may be able to justify an exclusion, such as EPA's authority to avoid a rule that would produce *de minimis* regulatory benefit. *See, e.g., id.* at 409, 412, 420.

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clear that there would be little or no regulatory benefit (the *de minimis* principle), and in many if not all cases it would be counterproductive (the absurd results principle), to impose PSD permitting requirements on projects that would burn forest products manufacturing residuals and similar materials, since discouraging or not permitting that activity would itself result in greater accumulation of GHGs in the atmosphere.[3] There is no judicial precedent, on the other hand, that would prevent EPA from excluding CO_2 emissions from burning biomass for energy recovery.

In addition to the examples set out above, there are numerous ways in which EPA has exercised its discretion in delineating the PSD program. A number of these regulatory precedents are particularly relevant for the differentiation of CO_2 emissions from using biomass for energy recovery. For example:

- EPA excludes from PSD permitting as "Volatile Organic Compounds" certain listed chemicals that are volatile and organic but that do not, once mixed with other pollutants in the atmosphere and exposed to sunlight, contribute appreciably to formation of ground-level ozone, the air pollution EPA seeks to mitigate through control of VOCs. In fact, in some situations EPA has excluded a chemical because, on balance, it can have an ameliorative effect on ground level ozone, even though in some circumstances it does contribute somewhat to ozone formation. EPA could rely on that same authority and analogous circumstances to exclude from PSD requirements the CO_2 produced when biomass is burned as a fuel, since those biogenic CO_2 emissions do not contribute to the build-up of GHGs in the global atmosphere.

- Similarly, EPA concluded it has discretion to define the pollutant "particulate matter" "to exclude particulates of a size or composition determined not to present substantial public health or welfare concerns." Thus, under the PSD regulations a modification may result in 2 ½ times as much emissions of coarse particulate matter than fine particulate matter without triggering PSD permitting. EPA could make similar distinctions in defining "greenhouse gases" (a term not even contained in the statute) for PSD purposes.

- In fact, EPA has already made distinctions in defining "greenhouse gases," and has done so based on the perceived impact in the environment of certain greenhouse gas emissions. EPA chose only to regulate six of the numerous compounds that may contribute to global warming, believed to represent about 75% of total anthropogenic heating. Other compounds thought to contribute less to global warming are not defined as "greenhouse gases," and therefore are not regulated, for PSD purposes. Likewise, EPA has differentiated even among the six greenhouse gases, based on the perceived relative contribution to anthropogenic heating that those pollutants have, over the long term when fully mixed in the global atmosphere. As a result, a source can emit 25 times more CO_2 than methane without triggering PSD permitting or BACT requirements. EPA could modify its definition of GHGs, on similar grounds, to exclude CO_2 emissions from biomass

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[3] Note that, in differentiating burning of biomass for energy recovery from fossil-fuel burning, EPA would be exercising its discretion to define the scope of the PSD permitting program and the terms Congress used when establishing that program. That approach differs conceptually and legally from concluding that all emissions of CO_2 from combustion of biomass for energy recovery are potentially included within the PSD program, but that offsets should be allowed for emissions from combustion of biomass for energy recovery to reflect carbon sequestration occurring at a different time and place.

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combustion generally, or from combustion of forest products manufacturing residuals and other listed activities specifically.

Given the discretion EPA has in defining applicability of the PSD program, and given the way EPA has used that discretion, in analogous ways and for analogous reasons, to exclude various other activities and pollutants from PSD review, it would be arbitrary and capricious not to distinguish CO_2 from use of biomass fuel from other GHG emissions.

EPA has already, in the Tailoring Rule, substantially modified operation of the PSD program with respect to GHGs by defining what (global-warming-potential-weighted) amount of GHGs will be considered "subject to regulation" under the CAA and therefore may trigger PSD permitting and BACT requirements. EPA could apply a similar approach to exclude biogenic CO_2 emissions that EPA determines are not contributing to the build-up of undesirable concentrations of GHGs in the global atmosphere.[4]

Note that, under its legal authority and consistent with its past implementation of the PSD program, EPA could make that determination to exclude biogenic CO_2 emissions based on its review of all of the environmental and energy consequences of subjecting those emissions to PSD permitting, rather than imposing some strict, quantitative analysis requirement for every potential new source or modification. To accomplish the goals of differentiating biogenic CO_2 in the PSD regulations, EPA should adopt a system that can be implemented easily and consistently and that minimizes uncertainty for source operators and their investors.

Conclusion

Regardless of how EPA chooses to identify biogenic CO_2 emissions that should be excluded from PSD permitting requirements because use of biomass as fuel is part of the carbon cycle and is not reducing carbon sequestration in biomass stocks, the regulations should contain categorical exclusions from PSD requirements for forest products manufacturing residuals and other similar types of residuals. Doing so would be consistent with the purposed of the Clean Air Act, environmental and energy goals, and prior EPA actions limiting the scope of the PSD program. Indeed, because the CO_2 emissions from burning forest products manufacturing residuals for energy recovery present less potential for global warming than the GHG emissions that would occur if the residuals were not burned for energy recovery, it would be counterproductive for EPA to subject that activity to PSD permitting.

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[4] As it did in other instances referred to above, EPA could choose to differentiate biogenic CO_2 in the PSD regulations either expressed in terms of the type of activity generating the emissions (as it has , e.g., for increasing hours of operation or installing clean-coal technology), or based on the inherent nature of the emissions themselves, as they affect the potential for global warming (as it has, e.g., in regulating all six GHGs on a CO_2-equivalent basis).

TABLE OF CONTENTS

I. Introduction

This paper explains why EPA is justified in concluding that combustion of biomass does not produce CO_2 emissions that contribute to the air pollution that EPA is seeking to address in applying the Clean Air Act Prevention of Significant Deterioration (PSD) permitting program to greenhouse gases, including CO_2. It also sets forth in detail how judicial precedent and past EPA actions defining the scope of the PSD permitting program allow, and indeed compel, EPA to differentiate between biogenic CO_2 emissions[5] and CO_2 emissions generated by combustion of fossil fuels.

This paper focuses in particular on the burning of forest products manufacturing residuals for energy recovery.[6] This appears to be the first time EPA has had to address fuel combustion that implicates avoided emissions: Unlike burning coal or other fossil fuels, burning forest products manufacturing residuals for energy recovery avoids GHG emissions that would occur if that biomass were not burned for energy recovery (so-called "anyway emissions"). In this way, burning forest products manufacturing residuals for energy recovery has an inherent effect of reducing anyway emissions of GHGs, an effect that EPA cannot reasonably ignore.

This paper first discusses the unique characteristics of biogenic CO₂ emissions, and in particular of CO_2 emissions from combustion of forest products manufacturing residuals, related

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[5] As defined in 40 C.F.R. § 52.21(b)(49)(ii)(*a*): carbon dioxide emissions resulting from the combustion or decomposition of non-fossilized and biodegradable organic material originating from plants, animals, or micro-organisms.

[6] As used here, forest products manufacturing residuals are forest-derived materials from pulp and paper mills, wood products manufacturing facilities, and downstream manufacturing facilities, including, but not limited to, spent pulping liquors, woody manufacturing residuals, paper recycling residuals, and wastewater and process water treatment plant residuals.

to climate change, and why it is important for EPA not to discourage use of biomass as fuel. Then it describes a variety of legal principles and judicial precedent that give EPA substantial latitude in defining applicability of PSD permitting requirements, consistent with the purposes of the Clean Air Act, including a discussion of the most recent precedents related to EPA's authority to fashion the PSD regulations. Next, the paper provides examples of how EPA has exercised that discretion in the past to limit applicability of PSD permitting requirements beyond what a narrow, literal reading of the CAA might suggest, including for GHGs in particular. These legal principles and regulatory precedents are then applied to the particular context of CO_2 emissions from combustion of forest products manufacturing residuals.

II. A different regulatory approach for biogenic CO2 emissions will support efforts to reduce the accumulation of GHGs in the atmosphere and reduce dependence on fossil fuels.

Biogenic CO_2 emissions differ from CO_2 emissions from combustion of fossil fuels in two critical ways: (1) combustion of fossil fuels adds carbon to the global atmosphere that had been, and would have remained, permanently sequestered underground, while biogenic CO_2 emissions are part of a carbon cycle in which CO_2 was extracted from the global atmosphere to produce, through photosynthesis, the biomass being burned; and (2) fossil fuels only emit GHGs when they are extracted and burned, while biomass will emit GHGs even if the biomass is not used as a fuel or feedstock. As further explained below, these unique aspects of emissions from biomass justify, indeed compel, a different regulatory approach.

A. Biogenic CO2 emissions are part of the short-term carbon cycle and do not contribute to climate change.

As EPA and international environmental organizations have long recognized, burning biomass for energy recovery is different from burning fossil fuel, from a potential climate change standpoint, because the carbon/CO_2 released when biomass is burned was removed from the global atmosphere in the recent past, when the organic carbon in the biomass was produced through photosynthesis, and CO_2 likewise is removed from the atmosphere when new biomass resources are grown to replace that which was harvested. This relatively rapid cycling of carbon in and out of the atmosphere does not contribute to the "air pollution" that EPA is seeking to address: the contribution of anthropogenic emissions of GHGs to undesirable concentrations of GHGs in the global atmosphere, a process that takes place over decades to centuries.[7] EPA has acknowledged this fundamental difference in numerous contexts.[8]

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[7] EPA stated that, for its endangerment finding for GHG emissions from motor vehicles, "the relevant time frame is decades to centuries for the primary greenhouse gases of concern." 74 Fed. Reg. 66,496, 66,514 (Dec. 15, 2009); *See also id.* at 66,517.

[8] *See, e.g.*, Renewable Fuel Standard 2, 75 Fed. Reg. 14,669, 14,787 (March 26, 2010) ("For renewable fuels, tailpipe emissions only include non-CO2 gases, because the carbon emitted as a result of fuel combustion is offset by the uptake of biogenic carbon during feedstock production."); EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007* (2009), pp. 3-2, 3-59 ("Biofuels such as wood and ethanol are also considered to be C neutral; although these fuels do emit CO_2, in the long run the CO_2 emitted from the biomass consumption does not increase atmospheric CO_2 concentrations if the biogenic C emitted is offset by the growth of new biomass."); *id.* at p. 3-1 ("It is assumed that the C released during consumption of biomass [through combustion of biomass and biomass-based fuels] is recycled as U.S. forests and crops regenerate, causing no net addition of CO2 to the atmosphere."); EPA, *Climate Leaders, Greenhouse Gas Inventory Protocol Core Module Guidance, Direct*

So, too, for example, has the State of Washington's Department of Ecology, which has recognized, with the Supreme Court of Washington's approval, that replacing fossil fuel with biomass will for this reason "decrease the total amount of carbon dioxide in the atmosphere." *PT Air Watchers, et al. v. State of Wash., Dep't of Ecology, et al.*, Sup. Ct. of Wash. No. 88208-8 (Feb. 27, 2014), slip op. at 10. The Court explained that the Department of Ecology

> acknowledge[s] that the burning of biomass, like the burning of fossil fuel, emits carbon dioxide into the atmosphere. However, they contend that the burning of biomass does not add to the total amount of carbon dioxide in the atmosphere. Biomass is part of the earth's carbon cycle, where plants take in carbon dioxide from the atmosphere and then release it when they decay or die. Biomass naturally releases this carbon dioxide if left on the forest floor to decompose. Forest fires and slash burning also release the carbon dioxide stored in biomass. In contrast, fossil fuels are not part of the earth's carbon cycle. Fossil fuels release carbon dioxide into the earth's atmosphere only when they are burned. When fossil fuel is replaced by biomass fuel, the new carbon dioxide that would normally be emitted from fossil fuel is replaced by carbon dioxide that will be emitted into the atmosphere regardless of whether the biomass is burned. [Washington Dept. of Ecology] contend[s] that, in this way, the replacement of fossil fuel with biomass fuel decreases the total amount of carbon dioxide in the atmosphere.

Id., slip op. at 8-9 (record citations omitted).

In the United States, biomass stocks currently represent a strong GHG sink, with U.S. forests alone sequestering over 15% of U.S. GHG emissions in 2012.[9] Hence, CO_2 from the combustion of biomass does not contribute to the "air pollution" that EPA intends to address through regulation of GHGs, namely the build-up of excessive GHGs in the global atmosphere. *See* 74 Fed. Reg. 66,496, 66,536 (Dec. 15, 2009); *see also id.* at 66,497 (discussing endangerment associated with "elevated concentrations of the [six] well-mixed greenhouse gases"), 66,516. EPA has described the "air pollution" that it is seeking to regulate as the flow of GHGs that changes the total, cumulative stock of greenhouse gases in the atmosphere. *Id.* at 66,526. Biomass combustion is one part of the continuous cycling of carbon between the atmosphere and biomass stocks. In contrast, fossil fuel combustion involves a one-way flow of carbon that increases the stock of GHGs in the atmosphere, because it adds to the atmosphere carbon that was removed from the atmosphere millions of years ago, that otherwise would have remained sequestered in the ground indefinitely, and that will not be removed from the atmosphere in the near future through regeneration of the fossil fuel.

Thus, so long as the growth of biomass is exceeding the amount harvested – as it does in the United States by a wide margin – biogenic CO_2 emissions should not be considered "air pollutants," and they do not contribute to "air pollution," because they are not part of the flow of

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Emissions from Stationary Sources, §1.2 (May 2008) (EPA430-K-08-003) ("[I]t is assumed that combustion of biofuels do not contribute to net addition of CO_2 to the atmosphere.").

[9] *See* EPA, Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012, Feb. 2014, at p. ES-20. *See also*, e.g., Heath, L.S., et al., Managed Forest Carbon Estimates for the U.S. Greenhouse Gas Inventory, 1990-2008, *Journal of Forestry* 109(3): 167-73 (2011) (finding that overall forest sequestration is increasing and projecting that forest carbon stocks will remain stable for the foreseeable future).

GHGs from sequestered carbon stocks into the atmosphere that results in excessive concentration of GHGs in the global atmosphere.[10] For that reason, biogenic CO_2 emissions can and should be distinguished from CO_2 emissions from combustion of fossil fuels in EPA permitting regulations.

B. Using biomass residuals for energy avoids GHG emissions from their alternative fate.

An additional, very important characteristic is presented by the combustion of forest products manufacturing residuals for energy recovery. Although burning forest products manufacturing residuals releases CO_2 (and minor amounts of methane and nitrous oxide) into the atmosphere from the oxidation of the biomass, it at the same time avoids emission of GHGs that would occur anyway if these residuals were not burned for energy recovery. A critical fact is that forest products manufacturing residuals arise from the harvesting and processing of biomass for the purpose of manufacturing products to meet societal needs, and of necessity the residuals will have to be disposed of – through abandoning in place, landfilling, incinerating, or wastewater treatment and discharge – if they are not used as an energy source. Because biodegradation of the forest products manufacturing residuals in various disposal scenarios can release far more methane than their combustion for energy recovery, and methane is considered to have a much greater impact on global warming than CO_2,[11] disposal of these residuals (i.e., not using them for fuel) in those cases can in fact result in significantly higher addition of GHGs to the atmosphere, in terms of global warming potential, than from their combustion for energy.

This special characteristic of forest products manufacturing residuals is documented in a report that has been submitted to EPA, National Council for Air and Stream Improvement, *Greenhouse Gas And Fossil Fuel Reduction Benefits of Using Biomass Manufacturing Residuals for Energy Production in Forest Products Facilities*, Technical Bulletin No. 1016 (Oct. 2013) (the "NCASI study"). The NCASI study constitutes the most comprehensive, robust scientific evaluation available of the relevant impact over time on global warming of using forest products manufacturing residuals as fuel versus their disposal. To summarize, the study shows that, if forest products manufacturing residuals are disposed of rather than burned for energy recovery, the cumulative radiative forcing from emissions associated with disposal will exceed the cumulative radiative forcing that would have been associated with burning the forest products manufacturing residuals for energy recovery in a very short time: between 0 and 7.7 years, depending on the type of residual, with a weighted average of 2.4 years for all forest products manufacturing residuals.[12] When the analysis takes into account the fact that, if forest products manufacturing residuals are not burned for energy recovery, there still will be GHG emissions

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[10]   The State of Washington's legislature has recognized this principle, by including in a statute aimed at reducing GHG emissions the proviso that: "Except for purposes of reporting, emissions of carbon dioxide from industrial combustion of biomass in the form of fuel wood, wood waste, wood by-products, and wood residuals shall not be considered a greenhouse gas as long as the region's silvicultural sequestration capacity is maintained or increased." R.C.W. § 70.235.020(3).

[11]   Viewed over a 100-year time frame, EPA believes that methane has 25 times greater impact on global warming per ton emitted than CO_2. *See* Table A-1 to 40 C.F.R. part 98 subpart A. Over a 20-year timeframe, the greater impact of methane emissions on the potential for global warming is even higher: According to Table 8.7 of the IPCC's *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, the 20-year global warming potential of methane is 86 times that of CO_2.

[12]   NCASI Study, *supra*, Table ES.5, at vi.

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associated with fossil fuels that are burned instead to meet the facility's energy needs,[13] then the cumulative effect on global warming from the disposal option exceeds the effect of emissions from burning the forest products manufacturing residuals for energy recovery in only 0 to 0.6 years, with a weighted average of only 0.2 years.[14]

The NCASI study further shows that the use of biomass residuals for energy in the forest products industry is a longstanding practice so that the break-even times under either analytic approach have already been met.[15] In other words, any "carbon debt" associated with the burning of forest products manufacturing residuals for energy has already been "paid back," and the current use of manufacturing residuals for bioenergy is resulting in net GHG avoidance benefits.

The study also shows that the benefits of using forest products manufacturing residuals for energy, rather than disposing of them are significant -- avoiding the emission of approximately 218 million metric tons of CO_2e per year.[16] Even if the analysis is limited only to avoided biogenic GHG emissions (ignoring the benefits of fossil fuel displacement and chemical recovery), the use of forest product manufacturing residuals for energy avoids approximately 65 million metric tons of CO_2e annually. This is roughly equivalent to removing about 10 million cars from the road.[17]

Thus, the NCASI study demonstrates unequivocally that, because combustion of forest products manufacturing residuals for energy recovery avoids the "anyway emissions" associated with disposal that otherwise would occur, such use actually has a favorable impact on the "air pollution" that EPA is attempting to address through regulation of GHGs under the CAA. Not only is application of the PSD program to biogenic CO_2 emissions an unnecessary regulatory burden with little or no regulatory benefit, but, in the case of CO_2 emissions from burning forest products manufacturing residuals for energy recovery, imposing the burdens of PSD permitting on projects involving their use as a fuel would actually be counterproductive to the goal of regulating GHG emissions.

Although the NCASI study and the following discussion focus primarily on forest products manufacturing residuals, other types of biomass burned for energy recovery, such as agricultural wastes, post-life products, or woody biomass from forest management or harvesting, may also have similar beneficial impacts on the build-up of GHGs in the global atmosphere.

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[13] EPA has recognized this reality: burning biomass to generate thermal energy or electricity means that fossil fuel will not be burned to meet that same energy demand, thus reducing the build-up of anthropogenic CO_2 in the global atmosphere. *See, e.g.*, EPA, Combined Heat and Power Partnership, "Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities: Market Analysis and Lessons from the Field" (Oct. 2011) pp. iv, 12-13 (using biogas from municipal wastewater treatment plants to generate electricity "reduces emissions of greenhouse gases"; just those plants that have already have anaerobic sludge digestion could avoid over 3 million tons of CO_2 per year – the equivalent of taking almost 600,000 cars off the road – by burning biogas to generate electricity and thereby displacing grid-supplied (and mostly fossil-fuel-generated) electricity).
[14] NCASI Study, *supra*, Table ES.3, at v.
[15] NCASI Study, *supra*, Table ES.6, at vii.
[16] NCASI Study, *supra*, Ex. Summary, at iii.
[17] According to EPA, the typical passenger motor vehicle emits 5.1 metric tons of CO_2 per year. EPA, Greenhouse Gas Emissions from a Typical Passenger Vehicle (Dec. 2011), *available at* http://www.epa.gov/otaq/climate/documents/420f11041.pdf. Hence, reducing 65 million tons of CO_2 a year is equivalent to taking 12.7 million cars off the road (65 million tons of CO_2/5.1 tons of CO_2 per car = 12.7 million cars).

These materials have "anyway emissions" of GHGs associated with their alternative, non-fuel fates that would result from the biodegradation of the material if left in place or from the landfilling, burning, or treatment of the material for disposal. For example, in some parts of the country the "slash" resulting from timber harvesting (tree tops, residual branches, etc.) is often collected and burned, leading to emissions of CO_2 and other pollutants without any energy benefit. Alternatively, if the slash is left in place, biodegradation of this material will emit GHGs, again without any energy benefit that might reduce the release of carbon sequestered in fossil fuel. Thus, as with forest products manufacturing residuals, this material will be generated regardless of whether it will be used as fuel, and its use as fuel therefore both substitutes for fossil fuel and avoids emissions of GHGs associated with its alternative fate.[18]

Similarly, municipal wastewater treatment plants generate biosolids that are part of the carbon cycle: atmospheric carbon is fixed when crops are grown as food, and then it is returned to the atmosphere after the plant material is eaten and the waste is collected at the wastewater treatment plant and either disposed of or burned. Biogas is generated by anaerobic digestion of the wastewater treatment plant sludge or by its anaerobic decomposition in a landfill. If that biogas (much of it methane with a much higher global warming potential than CO_2) is not burned for energy recovery, it will enter the atmosphere anyway (either directly, or after collection and incineration) and contribute to the excessive accumulation of GHGs in the global atmosphere that EPA is seeking to avoid. Just like burning forest products manufacturing residuals for energy recovery, using biogas as a fuel not only does not contribute to the "air pollution" EPA is addressing through application of PSD permitting to GHGs, but it actually reduces the concentration of GHGs, on a CO_2e basis, in the global atmosphere.[19]

Thus, using forest products manufacturing residuals and certain other types of materials for energy presents a unique situation such that the activity actually has a positive effect on the build-up of GHGs in the global atmosphere – the air pollution that EPA is attempting to address through application of PSD permitting to GHGs. One could also say that, because of the inherent GHG emissions associated with not using these biomass residuals for energy recovery, the emissions from combusting these biomass materials as fuel have a negative global warming potential. EPA has the authority to take these facts into account in defining the scope of PSD and Title V permitting regulations, and it would be inconsistent with Clean Air Act and other federal policy goals not to do so.

C. EPA should not discourage the use of biomass as fuel.

There are strong public policy justifications, expressed in congressional statements of purpose and in the President's statements on energy and climate change policy, for encouraging,

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[18] *See, e.g.*, Springsteen, et al., Emission Reductions from Woody Biomass Waste for Energy as an Alternative to Open Burning, *J. Air & Waste Mgmt. Assoc.* 61:63-68 (2011) (the Placer County Air Pollution Control District "and others report that the utilization of woody biomass waste for energy as an alternative to open burning [its primary current fate] can provide significant air emissions mitigation for criteria pollutants, air toxics, and greenhouse gases, along with energy benefits through production of renewable energy in a well-controlled conversion process.").

[19] *See* A. Listowski1, et al., Greenhouse Gas (GHG) Emissions from Urban Wastewater System: Future Assessment Framework and Methodology, 1 *J. of Water Sustainability* 113, 119 (June 2011) ("Wastewater treatment is also considered *a global warming mitigation factor*. Without proper treatment, the carbon in discharged wastewater will eventually enter the ecosystem as CH_4 (or CO_2), without the potentials for offset associated with biomass segregation and biogas energy recovery." (emphasis added)).

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and certainly not impeding, enhanced use of domestic, renewable fuels, including biomass.[20] In addition to avoiding the release of long-sequestered carbon from fossil fuels, these policy considerations include: slowing consumption of a finite and dwindling resource, providing stable and affordable energy for consumers, reducing dependence on foreign imports, improving the balance of trade, and reducing vulnerability to unstable countries and regions.

EPA has recognized the importance, in light of those energy and climate change policy goals, of facilitating the use of biomass for energy.[21] Failure to differentiate biogenic CO_2 emissions in the PSD permitting regulations not only would impose regulatory burdens on sources combusting biomass that could not be justified in terms of the goal of avoiding excessive concentrations of GHGs in the global atmosphere, but it also would create disincentives for combustion of biomass. Given the important benefits that biomass combustion has over fossil fuel combustion, in terms of potential contribution to global warming and also in terms of furthering other important national policy goals, it is imperative that EPA act to minimize those regulatory disincentives.

If EPA does not act to replace the challenged, and expiring, exemption from PSD permitting for biogenic CO_2 emissions in the Biomass Deferral Rule, the burden of PSD permitting will fall disproportionately on biomass. Due to the inherent nature of the combustion of biomass for energy recovery, in most instances for equivalent energy output a boiler firing biomass will emit a greater mass of CO_2 than a boiler firing fossil fuel.[22] As discussed above, however, although combustion of biomass may emit a greater amount of CO_2 than fossil fuels, CO_2 emitted from using biomass for fuel does not increase the atmospheric concentration of CO_2 over time, unlike CO_2 from fossil fuels.

If the PSD regulations do not recognize the fundamental differences, in terms of impact on the buildup of excessive concentrations of GHGs in the global atmosphere, between use of biomass fuel and use of fossil fuel, then those regulations would have the perverse effect of making it more difficult for a facility to increase its use of biomass fuel than to increase its use of fossil fuel, because of higher CO_2 emissions to produce the same amount of thermal energy from

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[20] *See, e.g.*, Exec. Off. of the President, Blueprint for a Secure Energy Future, March 30, 2011, pp. 3-5; introductory statement of the Energy Independence and Security Act of 2007, Pub. L. No. 110-140 (seeking to "move the United States toward greater energy independence and security [and] to increase the production of clean renewable fuels..."). EPA has recognized that use of biomass for energy production "can be part of the national strategy to reduce dependence on fossil fuels," and that "efforts are underway at the Federal, State and regional level to foster the expansion of renewable resources and promote bioenergy projects when they are a way to address climate change, increasing domestic alternative energy production, enhancing forest management and creating related employment opportunities." 76 Fed. Reg. 43,490, 43,492 (July 20, 2011). *See also* EPA statements on the benefits of electricity generated from biogas and "eligible biomass" as an environmentally superior source of "green power," at http://www.epa.gov/greenpower/gpmarket/.

[21] *See, e.g.*, 46 Fed. Reg. at 43,492 ("We believe part of fostering this development [of bioenergy to reduce dependence on fossil fuels] is to ensure that those feedstocks with negligible net atmospheric impact not be subject to unnecessary regulation.").

[22] Among other things, because biomass fuel generally has a significantly lower heat value and significantly higher moisture content than fossil fuel, in most cases a larger quantity of biomass has to be burned to generate the same amount of useful thermal energy. *See, e.g.*, Table C-1 to 40 C.F.R. part 98 subpart C, as amended November 29, 2013, 78 Fed. Reg. 71,904, 71,950-51 (default high heat value for coal is about twice as high per ton than for agricultural byproducts and about 50% higher than for wood and wood residuals once adjusted for typical moisture content in accordance with n.5).

biomass.[23] Due to the delays, uncertainties, and costs involved in PSD permitting, facilities may choose at the margin not to switch from fossil fuel to biomass fuel, or to meet the increased energy needs of expanded production through more fossil fuel combustion rather than more biomass combustion, in order to avoid triggering PSD permitting because of increased CO_2 emissions from biomass.

For example, in numerous instances a wood products facility that might use biomass to meet some or all of its energy needs, or a cogeneration or stand-alone electric power generator fired primarily with biomass, may not be considered a major stationary source subject to PSD and Title V permitting for any pollutant other than GHGs, nor would it be considered a major stationary source if biogenic CO_2 is excluded from the calculations.[24] Requiring a PSD permit for such a facility imposes "substantial" costs (see 75 Fed. Reg. at 31,568), delays the benefits of substituting biogenic CO_2 for CO_2 from combustion of fossil fuels, and, in some instances, may discourage implementation of the project altogether. Once a new facility or a modification of an existing facility is considered "major," by virtue of its biogenic CO_2 emissions, then under CAA section 165(e)(2) one year of pre-construction ambient air quality monitoring data must be supplied as part of the permit application. The facility would have to demonstrate, pursuant to 40 C.F.R. §§ 52.21(j)(2) and (3), that it is applying the Best Available Control Technology (BACT), not just for GHGs but for any other pollutant emitted in significant amounts. Ambient air quality modeling for those pollutants also would be required, under 40 C.F.R. §§ 52.21(k) and (m). Having to obtain a PSD permit generally will take over a year and will cost $100,000 or more, and that is before considering the capital and operating costs of additional pollution control equipment that may be required for one or more pollutants under the BACT requirements – which can be much greater than the administrative cost of obtaining the permit. In some cases, the delays, added costs, and uncertainties may make it infeasible to obtain financing for a new biomass-fired project.

Even if a new facility or a modification will need to get a PSD permit because of other pollutants, adding biogenic CO_2 to the pollutants that the permit applicant must analyze, and for which the project must demonstrate it is applying BACT, can add substantial costs and delays to a project. In its "Tailoring Rule," which initially only required consideration of GHG emissions in connection with PSD permitting of "anyway sources" that already would require a permit for pollutants other than GHGs, EPA acknowledged that even in those cases "sources and permitting

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[23] If a facility is being modified, and new or increased combustion of biomass is being substituted for existing fossil fuel combustion (e.g., where the facility is installing a new biomass boiler and shutting down a fossil-fuel-fired boiler), the "net emissions increase" from the project will be reduced by the amount of CO_2 emissions from fossil fuel that will be eliminated, but, for reasons described above, those emissions reductions will not be as great as the (biogenic) CO_2 emissions increase, even if the energy demand for the facility remains the same. If, on the other hand, the facility proposes to meet increased energy demand by recovering energy from biomass that otherwise would have been disposed of, the reduction in GHGs associated with the elimination of that disposal often will not, under the current PSD regulations, reduce the "net emissions increase" of GHGs at the facility, because those avoided GHG emissions generally would have occurred at a different location, and often under different ownership. The PSD regulations therefore would not allow those emission reductions to be included in the calculation of the net emissions increase from the project. *See* 40 C.F. R. §§ 52.21(b)(3), (5), and (6).

[24] For example, in their November 4, 2013 Cross Motion for Immediate Issuance of the Mandate in *Center for Biological Diversity v. EPA*, D.C. Circuit No. 11-1101, petitioners claimed, based on expert opinions, that all biomass-fired power plants constructed and proposed for construction since the Biomass Deferral Rule would be subject to PSD permitting only if biogenic CO_2 were included in determining whether PSD major source thresholds are exceeded.

authorities will still face substantial additional work to address the GHG emissions," including dealing with "significant and complex policy questions about how BACT will be implemented for GHGs," and "many case-specific policy issues...in the context of a specific permit application." 75 Fed. Reg. 31,514, 31,568 (June 3, 2010). Just for the permitting agency, EPA estimated that adding a requirement to analyze the impact of GHG emissions and demonstrate BACT for GHGs for projects required to obtain a PSD permit for other pollutants would add 23 percent to the time required to process PSD permits. *Id.*

Clearly, including biogenic CO_2 emissions in the determination of whether a new or modified source would exceed the threshold for requiring a PSD permit, or would have to demonstrate BACT for GHGs, will result in significant additional costs and delays for projects involving biomass combustion. EPA must take this additional burden on sources and permitting authorities, as well as the resulting delays and disincentives for desirable "green power" projects, into account when assessing the regulatory benefits, if any, of subjecting these new or modified sources to PSD permitting.[25]

Adopting policies that do not discourage use of biomass for energy will have undeniable, substantial benefits, both in terms of substituting biogenic CO_2 that is part of the carbon cycle for the reduction in geological carbon stocks that occurs when fossil fuels are burned, and in terms of furthering numerous domestic energy policy goals. In the case of combustion of forest products manufacturing residuals, there is the additional consideration, as explained above, that failure to use the residuals for energy recovery purposes will result in substantially higher concentrations of GHGs in the global atmosphere, over a relatively short period of time, due to the "anyway emissions" or negative GHG emission factor associated with the residuals if not used for fuel. Moreover, since most of that biomass will come from private lands, where a regulation that diminishes the value of timber (by reducing the ability or increasing the cost to use some of that biomass as an energy source) reduces a motivation for the landowners to continue to maintain their land in forests and convert additional lands to forests, avoiding unnecessary regulatory burdens on combustion of biomass will be an important factor encouraging continued and additional carbon sequestration in biomass stocks.[26] It is appropriate and necessary for EPA to take these consequences into account in its efforts to reduce the

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[25] Aside from pre-construction permitting, biomass-fired projects already face a number of comparative hurdles. The fact that most biomass-based fuels, being less energy-dense and with higher moisture content, will need to be burned in greater quantities to achieve the same thermal energy output, plus the greater variability of physical characteristics, heat value, and moisture content of solid biomass fuel, means that there typically is an economic penalty, in terms of the capital and operating cost of fuel handling and combustion equipment, associated with burning biomass. Pollution control equipment and ash management may impose greater costs for biomass-fueled boilers, as well. The difference in costs is particularly great when comparing use of biomass fuel against combustion of natural gas. While a biomass-fired boiler may still be the best choice for the facility, it is inevitable that fewer facilities will choose to meet their energy needs with a biomass boiler if permitting burdens also are structured to favor fossil-fuel-fired units.

[26] In addition, to the extent that a regulation reduces the value of forest lands, it removes an incentive for management of the forest for sustainable harvest, which may lead over time to increased transfer of carbon from forest stocks to the atmosphere through forest fires and insect damage. *See, e.g.*, Wear, D.N. and J.P. Prestemon, Timber market research, private forests and policy rhetoric, in *Southern Forest Science: Past, Present, and Future General Technical Report SRS-75*, Southern Research Station, USDA Forest Service, Ashville, NC (H.M. Raucher and K. Johnsen, eds. 2004) (explaining that economic return for forest products creates incentives for private forest stewardship).

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buildup of GHGs in the atmosphere, by adopting CAA regulations that do not discourage or inhibit combustion of biomass for energy recovery.

III.   **EPA has authority under the Clean Air Act and established principles of administrative law to treat biogenic CO_2 emissions differently for purposes of PSD permitting.**

A.   **Courts have recognized EPA's broad discretion in determining the scope of Clean Air Act programs, including PSD and Title V permitting, to effectuate the statutory purposes.**

Applying general principles of statutory construction and administrative law, courts give EPA substantial discretion, when implementing Clean Air Act requirements, in defining the scope of facilities, pollutants, and actions subject to regulation – provided, of course, that EPA's interpretation is reasonable; e.g., that its action is not arbitrary and capricious. A key consideration, in determining the reasonableness of EPA's interpretation of statutory provisions defining the scope of its regulatory programs, is the extent to which EPA's approach furthers the statutory purpose(s). EPA's actions determining the extent of those programs must, among other things, be supported by the facts, adequately explained, and not inconsistent. As explained below, EPA's recognized discretion in deciding the reasonable scope of CAA regulatory programs, as well as several general principles of administrative law, all would allow, if not compel, EPA to define the PSD and Title V permitting programs in a way that promotes, rather than inhibits, the beneficial use of biomass.

A consistent theme of EPA's implementation of CAA new source review requirements (both before and after Congress codified the PSD program and nonattainment new source review in the 1977 CAA Amendments) and of the court decisions reviewing EPA new source review regulations is that EPA is accorded substantial discretion in designing new source review requirements that address air quality protection goals without unduly interfering with economic development. In the landmark *Chevron* case, for example, the Supreme Court recognized that EPA had used a number of different definitions of "stationary source" and accorded deference to the Agency's flexible interpretation of CAA requirements "in the context of implementing policy decisions in a technical and complex arena." *Chevron U.S.A. Inc. v. Natural Resources Defense Council, Inc.*, 467 U.S. 837, 864 (1984). The Court looked to "the policy concerns that motivated the enactment of" new source review requirements, namely "to accommodate the conflict between the economic interest in permitting capital improvements to continue and the environmental interest in improving air quality." *Id.* at 851, 863. Similarly, the Supreme Court found in a more recent case that EPA has substantial discretion to interpret the term "modification" to mean different things in different provisions of the CAA, again, taking into consideration the congressional objectives for the different provisions. *Environmental Defense v. Duke Energy Corp.*, 549 U.S. 561, 574-76 (2007).

EPA has, throughout its implementation of the PSD program, interpreted the requirements to best accommodate the policy goals involved, even if a narrow, literal application of the statutory directive might appear inconsistent with EPA's approach. For example, EPA early on concluded that an increase in hours of operation or production rate should be excluded from the definition of "major modification," because "forcing companies to obtain a PSD permit before they could simply adjust operating hours 'would severely and unduly hamper the ability

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of any company to take advantage of favorable market conditions.'" *Duke Energy*, 549 U.S. at 578-79 (citing 45 Fed. Reg. 52,676, 52,704 (August 7, 1980)). The Supreme Court has approved of that sort of rational implementation of the statutory requirement. *Id.* Likewise, courts have deferred repeatedly to EPA's sometimes-convoluted rules about how to determine whether a modification will result in a net emissions increase and therefore requires a PSD permit. *See, e.g., New York v. EPA*, 413 F.3d 3 (2005) (*New York I*) ("In enacting the NSR program, Congress did not specify how to calculate 'increases' in emissions, leaving EPA to fill in that gap while balancing the economic and environmental goals of the statute." (citing *Chevron*, 467 U.S. at 843-44)); *Duke Energy*, 549 U.S. at 578-79.

Indeed, the ability to make appropriate exceptions is inherent in Congress's delegation of the rulemaking power to EPA, unless Congress has been extraordinarily prescriptive in the legislation. EPA's discretion to shape the details of the PSD program consistent with the congressional purposes comes both from the generality of the terms that Congress used in mandating the PSD program, as discussed above, and from a specific provision of the CAA, section 301(a)(1), which grants the Administrator authority "to prescribe such regulations as are necessary to carry out his functions under" the Act. *See Citizens to Save Spencer County v. EPA*, 600 F.2d 844, 873 (D.C. Cir. 1979) (EPA may use its section 301(a) authority to harmonize inconsistent guidelines related to the implementation of federal preconstruction review requirements); *cf. Western Nebraska Resources Council v. USEPA*, 943 F.2d 867, 870 (8th Cir. 1991) (rejecting contention that EPA, having defined regulated aquifers broadly, could not create exceptions).

In interpreting the permissible scope of its regulations, EPA appropriately looks to the functional context – whether the scope of the regulation matches the regulatory benefit Congress was attempting to provide. For example, in *Coalition for Responsible Regulation v. EPA*, 684 F.3d 102, 134-36 (D.C. Cir. 2012), *cert. granted* (2013), the court upheld EPA's interpretation that the broad definition of "air pollutant," preceded by the "expansive" term "any," nevertheless should be limited, for PSD applicability purposes, to "any air pollutant regulated under the CAA." The reason the Court accorded EPA such leeway was because: "It is absurd to think that Congress intended to subject stationary sources to the PSD permitting requirements due to emissions of substances that do not 'endanger public health or welfare.'"[27]

B. Several general principles of administrative law give EPA discretion to determine the applicability of PSD permitting requirements.

In addition to this general discretion accorded to EPA in interpreting the CAA under *Chevron* and subsequent cases, as discussed above, there are a number of principles of administrative law that EPA has invoked to adopt a practical approach to implementing the PSD program, summarized below.

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[27] *Id.* at 134 (citation omitted). *See also Train v. Colorado Public Interest Research Group, Inc.*, 426 U.S. 1 (1976) (affirming EPA's interpretation of the Clean Water Act's broad definition of "pollutant," which specifically included "radioactive materials," as nonetheless allowing EPA to exclude from CWA regulations "source, byproduct, and special nuclear materials," because they are subject to regulation under the Atomic Energy Act). Moreover, agencies may revise their interpretation of the appropriate scope of the statute as their experience carrying out the objectives of the statute increases. *See Mass. v. EPA*, 549 U.S. 497, 524 (2007) ("Agencies...do not generally resolve massive problems in one fell regulatory swoop....They instead whittle away at them over time, refining their preferred approach as circumstances change and as they develop a more-nuanced understanding of how best to proceed.").

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1. Avoiding requirements that would produce little or no regulatory benefit

When reviewing the first set of PSD regulations that EPA adopted after the 1977 CAA Amendments, the D.C. Circuit rejected EPA's attempt to apply PSD only to "major" modifications, because the statute contains no such restriction. *Alabama Power Co. v. Costle*, 636 F.2d 323, 399-400 (D.C. Cir. 1979). At the same time, though, the Court stated clearly that EPA did have authority to exempt from the permit requirements those changes that had a *de minimis* impact on air quality, despite the lack of any exclusion in "the literal terms of [the] statute." *Id.* at 360. As EPA explained when the Agency first adopted significant net emissions increase levels to define "modifications" subject to PSD, the *Alabama Power* decision recognized that certain modifications to new sources "could be exempted from some or all PSD review requirements on the grounds that such emissions would be *de minimis*. In other words, the Administrator may determine levels below which there is no practical value in conducting an extensive PSD review." 45 Fed. Reg. at 52,705. In fact, *Alabama Power* held that EPA could not require a PSD permit for a change in an existing source – despite statutory language that appears to require a PSD permit for any physical change – if that change, together with contemporaneous changes at the source, would not result in a significant net increase in emissions of the pollutant in question. *See* 536 F.2d at 401, 403; 48 Fed. Reg. 38,742, 38,749 (Aug. 25, 1983).

While *Alabama Power* dealt specifically with exceptions to the definition of "modifications" subject to PSD permitting requirements, courts have applied the *de minimis* doctrine as described in *Alabama Power* to many other EPA rulemakings and many other federal agency regulations. For example, in *Environmental Defense Fund, Inc. v. EPA*, 82 F.3d 451, 465-66 (1996), the D.C. Circuit upheld an EPA regulation that excludes certain categories of federal activities, as well as those activities that do not affect "major" emission sources, from the SIP conformity determinations that CAA section 176(c)(1) literally requires for "any activity" of the Federal Government. The Court relied on *Alabama Power*'s statement that "categorical exemptions from the requirements of a statute may be permissible" to avoid imposing requirements on activities that "in context may fairly be considered *de minimis*." *Id.* at 466.

Similarly, in *State of Ohio v. EPA*, 997 F.2d 1520, 1534-36 (D.C. Cir. 1993), the D.C. Circuit approved EPA's promulgation of a *de minimis* exemption from a statute requiring periodic review of certain Superfund sites. EPA's regulation required periodic review only of sites where hazardous substances remained at levels precluding unrestricted use of and exposure to the site (thus exempting sites at which a nonhazardous amount remained), even though the statute requires periodic review for a site at which "any hazardous substances" remain. *See also*, e.g., *Ass'n of Admin. Law Judges v. FLRA*, 397 F.3d 957, 962 (D.C. Cir. 2005) ("Unless it has been 'extraordinarily rigid' in expressing itself to the contrary, …the Congress is always presumed to intend that 'pointless expenditures of effort' be avoided."); *Wisconsin Dep't of Revenue v. William Wrigley, Jr., Co.*, 505 U.S. 214 (1992) ("absent contrary indication," all statutes are deemed to incorporate the *de minimis* doctrine); *Indus. Union Dep't v. Am. Petroleum Inst.*, 448 U.S. 607, 663-64 (Burger, J., concurring) (describing the "heavy responsibility" that the Secretary of Labor has, when promulgating an OSHA health standard, "to refrain from regulation of insignificant or *de minimis* risks. When the administrative record reveals only scant or minimal risk of material health impairment, responsible administration calls for avoidance of extravagant, comprehensive regulation." (citation to *Alabama Power* omitted)). The *de minimis* principle does not allow an agency to "thwart a statutory command," but rather it can be a means

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of "'implementing the legislative design.'" *Public Citizen v. Young*, 831 F.2d 1108, 1113 (D.C. Cir. 1987) (quoting *Alabama Power*, 636 F.2d at 360-61).

Courts are not expected to second-guess EPA's judgment that a category of activities should be exempted from regulation when the Agency determines that its inclusion would result in a *de minimis* regulatory benefit. The D.C. Circuit has indicated that the same standard used in reviewing an agency's interpretation of an ambiguous statutory provision – namely, deferring to any "permissible" agency interpretation (see *Chevron*) – should be used in reviewing an agency's decision to create a *de minimis* exception. *Environmental Defense Fund*, 82 F.3d at 467 (D.C. Cir. 1996), citing *State of Ohio v. EPA*, 997 F.2d at 1535, *Western Nebraska Resources Council*, 943 F.2d 867, 870 (8th Cir. 1991), and *Chevron*, 467 U.S. at 83.

2. Deviating from literal application of the statute where it would lead to absurd or counterproductive results

The *de minimis* doctrine is a close relative to the doctrine that an agency is not required to follow a literal application of the statute if to do so would result in "absurd results." *See, e.g.*, *American Water Works Ass'n v. EPA*, 40 F.3d 1266, 1271 (D.C. Cir. 1994) (EPA need not follow "plain meaning" of a statutory term "where a literal reading of a statutory term would lead to absurd results"); *Alabama Power*, 636 F.2d at 360 n.89; *United States v. Am. Trucking Ass'ns*, 310 U.S. 534, 543 (1940) (Court will look beyond the plain meaning of the words of the statute, to consider the statute's purpose, when the plain meaning "has led to absurd or futile results"); *Public Citizen v. U.S. Dep't of Justice*, 491 U.S. 440, 454 (1989) ("Where the literal meaning of a statutory term would 'compel an odd result,' …we must search for other evidence of congressional intent to lend the term its proper scope." [citations omitted]).

The term "absurd results doctrine" is something of a misnomer: The doctrine allows an agency to divert from the literal meaning of a statute not only where "'acceptance of that meaning would lead to absurd results'" literally, but also where it "'would thwart the obvious purpose of the statute.'" *In re Trans Alaska Pipeline Rate Cases*, 436 U.S. 631, 633 (1978) (quoting *Commissioner v. Brown*, 380 U.S. 563, 571 (1965)). "[T]he literal meaning of a statute need not be followed where the precise terms lead to absurd or futile results, <u>or</u> where failure to allow a *de minimis* exception is contrary to the primary legislative goal." *Ohio v. EPA*, 997 F.2d at 1535, citing *Public Citizen v. Young*, 831 F.2d 1108 (D. C. Cir. 1987) (emphasis added).[28] In that connection, the congressional purposes that may guide a departure from literal application of statutory language is broader than just the specific purpose of the provision in question. *See, e.g.*, *Public Citizen v FTC*, 869 F.2d 1541, 1557 n.33 (D.C. Cir. 1989) (agency need not apply the language of the statute in a literal manner if this leads to "patently absurd results that will undermine Congress' broader purposes"); *Am. Trucking*, 310 U.S. at 543-44 ("When that [plain] meaning has led to absurd or futile results, however, this Court has looked beyond the words to the purpose of the Act. Frequently, however, even when the plain meaning did not produce absurd results but merely an unreasonable one 'plainly at variance with the policy of the

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[28] *See also*, e.g., *Bob Jones Univ. v. United States*, 461 U.S. 574, 586 (1983) ("It is a well-established canon of statutory construction that a court should go beyond the literal language of a statute if reliance on that language would defeat the plain purpose of the statute."); *United States v. Bryan*, 339 U.S. 323, 338 (1950) (refusing to apply the literal language where "congressional purpose would be frustrated"); *Arkansas Dairy Coop. Ass'n v. U.S. Dep't of Agriculture*, 573 F.3d 815, 829 (D.C. Cir. 2009) *cert. denied*, 130 S. Ct. 1066 (2010); *Engine Mfrs. Ass'n v. EPA*, 88 F.3d 1075, 1088 (D.C. Cir. 1996).

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legislation as a whole' this Court has followed that purpose, rather than the literal words."
[citations omitted]). *See also* 75 Fed. Reg. at 31,542-43).

The absurd results doctrine has been applied specifically to uphold EPA regulations
adjusting PSD applicability requirements. *See, e.g., Spencer County*, 600 F.2d at 871 & n.123
("'The policy [reflected in congressional intent] as well as the letter of the law is a guide to
decision ... to ameliorate ... [the law's] seeming harshness or to qualify its absolutes...'" (citation
omitted); *id.* at 870 n.119 (citing *Kenai Peninsula Borough v. Andrus*, 436 F. Supp. 288, 291 (D.
Alaska 1977) for the proposition that statutory construction is favored that "does not lead to
absurd or impracticable results"); *Alabama Power*, 636 F.2d at 360; *Coalition for Responsible
Regulation*, 684 F.3d at 134 (affirming EPA's interpretation that PSD permitting applies only to
those air pollutants subject to emission limits under the CAA because it "is absurd to think that
Congress intended" otherwise). Note that, in the case of the PSD program, the policy goals that
the absurd results doctrine may be applied to include both preventing "significant" further
deterioration of air quality <u>and</u> assuring that the permitting program does not excessively or
unnecessarily interfere with economic activity. *See, e.g., New York v. EPA*, 443 F.3d 880, 886
(D.C. Cir. 2006), *cert. denied sub nom. Utility Air Regulatory Group v. New York* (2007) (*New
York II*) (discussing "Congress's goal in adopting the 1977 amendments of establishing a balance
between economic and environmental interests"); *id.* at 887, 889; *Chevron*, 467 U.S. at 851
(describing the balance between "the economic interest in permitting capital improvements to
continue and the environmental interest in improving air quality").

3. Avoiding literal application of statutory provisions out of administrative necessity

Also closely related to the *de minimis* and absurd results doctrines is that of
"administrative necessity." EPA explained the doctrine in its brief in litigation over its GHG
PSD regulations:

> Under the doctrine known as "administrative necessity," "an agency may
> depart from the requirements of a regulatory statute ... to cope with the
> administrative impossibility of applying the commands of the substantive
> statute." *EDF v. EPA*, 636 F.2d 1267, 1283 (D.C. Cir. 1980). *See also Sierra
> Club v. EPA*, 719 F.2d 436, 463 (D.C. Cir. 1983); *Public Citizen, Inc. v.
> Shalala*, 932 F. Supp. 13, 17 (D.D.C. 1996). Even where the agency is *not*
> authorized to create a *de minimis* or other type of exemption, "administrative
> necessity may be a basis for finding implied authority for an administrative
> approach not explicitly provided in the statute [where 'applying the commands
> of the substantive statute'] would, as a practical matter, prevent the agency
> from carrying out the mission assigned to it by Congress." *Alabama Power*,
> 636 F.2d at 358. *See also New York v. EPA*, 443 F.3d 880, 888 (D.C. Cir.
> 2006).

Coalition for Responsible Regulation v. EPA, D.C. Cir. No. 10-1073, Final Brief for
Respondents (Dec. 14, 2011) at 58-59. EPA noted that the administrative necessity doctrine is
distinct from the *de minimis* doctrine and, therefore, can justify a departure from literal
application of statutory language even in situations where the activities at issue are not truly *de
minimis. Id.* at 59 n.13.

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In fact, the definitions and exclusions that EPA has used to construct a PSD program which implements the dual goals of protecting air quality and allowing continued economic development, while they often could be described as avoiding requirements that would achieve *de minimis* regulatory impact, have not been so limited. *See, e.g.*, EPA's Petition for a Writ of *Certiorari* in *EPA v. State of New York*, S. Ct. No. 06-736, at 18 ("[A]ll of EPA's long-standing regulatory exclusions allow, and some necessarily contemplate, excluding from NSR and NSPS at least some activities that could lead to more than de minimis increases in emissions. Those exclusions date from before Congress adopted the statutory NSR program in 1977. Yet Congress did not repudiate EPA's settled understanding of those terms."). *See also Alabama Power*, 636 F.2d at 400 ("EPA does have discretion, in administering the statute's modification provision, to exempt from PSD review some emission increases on grounds of *de minimis* or administrative necessity." (emphasis added)).

C. Recent D.C. Circuit opinions confirm EPA's ability to rely on administrative law concepts to depart from a strict reading of statutory directives where warranted.

Recent case law interpreting EPA's authority to craft PSD regulations has not undercut the availability of these legal doctrines and the extent of EPA's discretion in administering the PSD program.

In *New York I*, the D.C. Circuit vacated the expanded pollution control project exemption and the "clean unit" applicability test that EPA had added to the PSD regulations on December 31, 2002. The Court rejected the "innovative approach to NSR" that EPA attempted with the clean unit applicability test, because it defined a "major modification" without regard to whether emissions actually would increase. 413 F.3d at 38-40. EPA's support for the pollution control project exemption included a claim that it would be "absurd" to discourage pollution control projects by subjecting them to PSD. While not denying that absurd results could justify a departure from literal application of the statute, the Court was not convinced, by this "bare assertion of absurdity," that in fact Congress did not intend for pollution control projects to be evaluated under PSD, to the extent that they can result in increased "collateral" emissions of some pollutants. *See* 413 F.3d at 41.

The *New York I* Court upheld a number of EPA's 2002 amendments to the PSD regulations, and in so doing it emphasized EPA's discretion to decide how to calculate whether a modification will result in an "increase" in emissions. *See* 413 F.3d at 22-23; *id.* at 27 ("In enacting the NSR program, Congress did not specify how to calculate 'increases' in emissions, leaving EPA to fill in that gap..."). "There can be no doubt that EPA is entitled to balance environmental concerns with economic and administrative concerns, at least to a point.... Different interpretations of the term 'increases' may have different environmental and economic consequences, and in administering the NSR program and filling in the gaps left by Congress, EPA has the authority to choose an interpretation that balances those consequences." *Id.* at 23-24. The Court approved of EPA's choice of a fixed, 10-year "lookback" baseline for determining whether actual emissions would increase, deferring to EPA's "policy choice," intended, based on EPA's lengthy regulatory experience, "to promote operational flexibility and administrative efficiency." *Id.* at 26. The Court noted with approval EPA's consideration, in deciding how to define emission "increases," of the "overall" environmental consequences of the 10-year lookback, including benefits from "eliminat[ing] the regulatory disincentive for sources to implement changes that improve operating efficiency and reduce emission rates." *Id.* at 28-29.

Similarly, the *New York I* Court deferred to EPA's discretion to determine how emissions increases should be calculated, approving EPA's adoption of a "Plantwide Applicabity Limit" (PAL) approach to defining whether a modification would result in a significant net emissions increase. 413 F.3d at 36-37. "[B]alancing…the environmental, economic, and administrative goals of the CAA," and finding that the PAL approach would improve overall emissions over time – by shifting growth in emissions to cleaner units and by reducing the administrative burden of making changes that improve efficiency and reduce emission rates – EPA had the freedom to adopt a PSD applicability provision that in effect ignored emissions increases so long as they would not cause the PAL to be exceeded. *See* 413 F.3d at 37-38.

Thus, *New York I* reaffirmed EPA's broad discretion in defining PSD applicability, and it approved of EPA applying a number of practical considerations in deciding how to define modifications subject to PSD review.

In *New York II*, the D.C. Circuit rejected and vacated EPA's "equipment replacement rule," which had modified EPA's regulations that exempt from PSD changes associated with routine maintenance, repair, and replacement ("RMRR"), in a way that reduced the number of projects requiring a PSD permit. Under the equipment replacement rule, any replacement of components that cost less than 20 percent of the entire unit's replacement cost was defined not to be a "change" and therefore not to trigger PSD as a modification, regardless of whether and to what extent the replacement resulted in increased emissions. 443 F.3d at 883. The Court found the equipment replacement rule to be plainly inconsistent with the statutory definition of "modification," which centers on whether the change increased emissions, rather than the relative cost of implementing the change. *Id.* at 886-88. EPA did not attempt to justify the equipment replacement rule as an exercise of *de minimis* discretion, nor did it claim that the RMRR absent the equipment replacement rule was absurd or futile. *See* 443 F.3d at 888; 70 Fed. Reg. 33,838, 33,842 (June 10, 2005); 68 Fed. Reg. 61,248, 61,272 n.14 (Oct. 27, 2003). But the *New York II* Court did recognize and discuss the *de minimis* doctrine with respect to the RMRR exclusion generally. It stated that the RMRR exclusion is "consistent with Alabama Power" (443 F.3d at 884) and "reflects an agency's inherent power to overlook 'trifling matters,' [*Alabama Power*] at 360, a 'principle [that] is a cousin of the doctrine that, notwithstanding the 'plain meaning' of a statute, a court must look beyond the words to the purpose of the act where its literal terms lead to 'absurd or futile results,'' *id.* at 360 n. 89 (citations omitted)." 443 F.3d at 888.

The most recent case addressing EPA's authority to define PSD applicability is *Sierra Club v. EPA*, 705 F. 3d 458 (D.C. Cir. 2013). That decision vacated a portion of the PSD rules, adopted in October 2010, allowing applicants to avoid collecting and submitting preconstruction monitoring data required by CAA section 165(e)(2) for $PM_{2.5}$ if they could show that the modeled ambient impact from the source was below a specified "significant monitoring concentration" (SMC).[29] The Court rejected EPA's reliance on the *de minimis* doctrine to justify that exemption, because it concluded that "Congress was 'extraordinarily rigid' in mandating preconstruction air quality monitoring." 705 F.3d at 466. The Court relied almost entirely on

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[29] *See* 40 C.F.R. § 52.21(i)(5)(*i*)(*c*). The decision only vacated the SMC for $PM_{2.5}$; SMCs for other pollutants that EPA adopted in 1980 remain in effect, as does a provision that allows the permitting authority to decide, on a case-by-case basis, to exempt from preconstruction monitoring pollutants for which EPA has not promulgated an SMC. *See* 705 F.3d at 459-60; *see also* 78 Fed. Reg. 73,698 (Dec. 9, 2013) (revising only the SMC for $PM_{2.5}$); *cf.* 40 C.F.R. §§ 52.21(m)(5)(*i*), (*iii*).

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Alabama Power which, as noted above, had explained that agencies generally have "authority to provide an exemption when the burdens of regulation yield a gain of trivial or no value," except in the case where "Congress has been extraordinarily rigid...." 636 F.2d at 360-61. Since CAA section 165(e)(2) says that the analysis of ambient air quality impact required for a PSD permit "shall include continuous air quality monitoring data," and "such data shall be gathered over a period of one calendar year preceding the date of application for a permit," the Court found an "extraordinarily rigid" requirement from which EPA could not grant *de minimis* exceptions.

The Court noted that *Alabama Power* itself had held that EPA could not dispense with air quality monitoring requirements, despite technical limitations of monitoring equipment at the time, because CAA section 165(e)(2) states "a plain requirement for inclusion of monitoring data" in the evaluation of a PSD permit. 705 F.3d at 467, citing 636 F.2d at 372. The *Sierra Club* Court emphasized that Congress used the word "shall" twice in CAA section 165(e)(2), noting that Congress used less-rigid language in other parts of the PSD portion of the statute. *Id.* at 467, 468. The Court explained as well that the fact that CAA section 165(e)(2) does explicitly allow the permitting authority to grant one exception (i.e., monitoring for less than the generally required one year) suggests that Congress did not intend any other exceptions. *Id.* at 467.

Again citing *Alabama Power*, the Court said that an agency's implied authority to provide *de minimis* exemptions does not extend to the case where regulations would "provide some benefits, in the sense of furthering regulatory objectives, but the agency concludes that the acknowledged benefits are exceeded by the costs." 705 F.3d at 469, quoting *Alabama Power*, 636 F.2d at 361. "Although the year-long preconstruction monitoring requirement may be onerous and, in some cases, EPA deems it more costly than beneficial, the EPA may not substitute its policy for that of Congress." *Id.* at 469. Clearly, the Court's conclusion that EPA lacked discretion to adopt the SMC for $PM_{2.5}$ was very specific to the explicit statutory requirements related to preconstruction monitoring.[30] The decision is consistent with *Alabama Power* and does nothing to diminish EPA's broad authority to tailor the PSD regulations to avoid rules with *de minimis* regulatory benefit, as described in *Alabama Power* and exercised by EPA in subsequent PSD rules.

With respect to GHGs in particular, the primary case to date addressing EPA's authority under the PSD provisions of the CAA, *Coalition for Responsible Regulation, Inc. v. EPA*, 684 F.3d 102, 134-35 (D.C. Cir. 2012), *cert. granted* (2013), did not evaluate any of the administrative law principles EPA relied on in promulgating the Tailoring Rule and thereby excluding large amounts of GHGs from PSD permitting. Although the state petitioners asserted in their briefs that the absurd results doctrine could not justify modifying a specific statutory directive, such as the annual emission thresholds in the statutory definition of "major emitting facility" for PSD applicability, the Court dismissed all challenges to the Tailoring Rule for lack of standing without reaching those arguments.[31] (Nor are those arguments addressed in the

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[30] To date, no reported case has cited this *Sierra Club* opinion with respect to its application of the *de minimis* doctrine.

[31] 684 F.3d at 113-14. The non-state petitioners did not argue that the absurd results doctrine could never be used to depart from a literal application of the CAA PSD provisions, but rather that EPA was obligated to adopt a permissible interpretation of the CAA that was available and that would avoid absurd results. *See, e.g.,* Joint Opening Brief of Non-State Petitioners and Supporting Intervenors, D.C. Cir. No. 10-1075 (June 20, 2011) at 21. The state petitioners also argued that EPA should have avoided the absurd results problem in the first place by adopting an interpretation of the CAA that would not require PSD permitting for GHGs. Opening Brief of State Petitioners and Supporting Intervenor, at 19, 50-51.

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question on which the Supreme Court has granted *certiorari*.) None of the petitioners claimed that EPA had improperly invoked the *de minimis* doctrine, and EPA stated in its brief in that case: "The administrative necessity doctrine is distinct from a *de minimis* exemption that an agency may use to exempt certain small levels of emissions from statutory requirements. *Alabama Power*, 636 F.2d at 358-360; *New York v. EPA*, 443 F.3d at 888-89. In this case, EPA relied on the administrative necessity and absurd results doctrines, not a *de minimis* exemption. 75 Fed. Reg. at 31,560." Final Brief for Respondents at 59 n.13.

The D.C. Circuit's recent decision in *Center for Biological Diversity v. EPA*, 722 F.3d 401 (D.C. Cir. 2013) involved GHGs and the PSD program, and biogenic CO_2 emissions in particular, but it did not concern directly EPA's ability to differentiate biogenic CO_2 emissions in applicability provisions in the PSD regulations. That case addresses[32] EPA's authority to grant a temporary exclusion of biogenic CO_2 emissions from PSD permitting (the "Deferral Rule"), and it does not foreclose EPA's discretion to provide different treatment for biogenic CO_2 emissions on a permanent basis. In arguing that case, EPA did not even attempt to justify the Deferral Rule on *de minimis* grounds, saying that the *de minimis* principle would apply to a permanent, but not a temporary, exclusion. *See* 722 F.3d at 409. The majority's holding was based on the conclusion that the Deferral Rule's invocation of various other administrative law doctrines was not adequately supported by the rulemaking record. *Id.* at 410 (EPA "failed to explain" why the one-step-at-a-time doctrine applied); *id.* at 411 (EPA "should have explained why it rejected" a potentially less restrictive alternative under the administrative necessity doctrine); *id* at 412 (finding EPA's reliance on the absurd results doctrine to be "*post hoc*" because EPA made only "passing references" to absurd results in discussing the basis for the Deferral Rule).

Significantly, none of the three opinions in the case suggested that EPA lacked authority to permanently exclude biogenic CO_2 emissions from the PSD and Title V permitting programs. Two of the opinions suggested that EPA retained the broad authority described above to permanently exclude biogenic CO_2 emissions, provided the Agency justified its decision in the rulemaking record. *Id.* ("leav[ing] for another day the question whether the agency has authority under the Clean Air Act to permanently exempt biogenic carbon dioxide sources from the PSD permitting program"); *Id.* at 420 (Henderson, J. dissenting) (recognizing the "availability of a *de minimis* exception" to permanently exclude biogenic CO_2 emissions from PSD and Title V).[33] Even the concurring opinion, which concluded that the three doctrines of administrative law EPA relied on as authority for the Deferral Rule (not including the *de minimis* doctrine) could not "trump" applicability provisions of the statute, suggested that EPA still had the ability to permanently exclude biogenic CO_2 emissions. *Id.* at 413 n.1 (Kavanaugh, J., concurring) (suggesting that EPA could exclude biogenic CO_2 emissions by amending its Endangerment Finding). The majority opinion specifically rejected the suggestion by the dissent that the majority was implicitly denying EPA's ability to exempt biogenic CO_2 emissions in a final rule, specifically by applying the *de minimis* doctrine.[34] Thus, while the Deferral Rule litigation

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[32] The case has not yet been resolved; the D.C. Circuit has extended the date for petitioning the Court for rehearing until after the Supreme Court resolves the writ of *certiorari* in *Coalition for Responsible Regulation*.

[33] *Cf. Massachusetts v. EPA*, 415 F.3d 50, 66 (D.C. Cir. 2005), *rev'd* 549 U.S. 497 (2007) (Tatel, J., dissenting) (EPA presumably would not seek even voluntary reductions in GHGs "if it thought emissions reductions would have no discernible impact on future global warming").

[34] *See id.* at 412. The majority was disavowing the dissent's suggestion that the "necessary implication of the majority opinion is that," regardless of EPA's findings about the effect of biogenic CO_2 emissions on global warming, "EPA lacks authority to treat biogenic CO_2 emissions differently from other emissions" for PSD

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highlights the importance of providing a strong legal and factual basis for excluding biogenic CO_2 emissions from regulation, nothing in the decision indicates that EPA will be foreclosed from permanently excluding, or otherwise differentiating, biogenic CO_2 emissions at the conclusion of its reconsideration process.

IV.   EPA has applied this discretion to make analogous exceptions to PSD applicability in the past.

EPA has, throughout its implementation of the PSD program, made adjustments from a literal, uniform application of permitting requirements, often with explicit court approval, for reasons similar to the facts described above that compel differentiated treatment of biogenic CO_2 emissions. Some of those provisions are described below. In a number of instances, EPA's approach has been challenged and upheld by the courts. In any event, EPA's exercise of its discretion in this manner over the 35+ year course of its implementation of the PSD program is strong support for exercising similar flexibility in dealing with biogenic CO_2 emissions. *See, e.g., Entergy Corp. v. Riverkeeper, Inc.*, 556 U.S. 208, 129 S. Ct. 1498, 1509 (2009) (historic practice in applying a statute "tends to show that the EPA's current practice is a reasonable and hence legitimate exercise of its discretion"). In fact, given EPA's clear discretion to do so, and its exercise of that discretion in similar ways in the PSD regulations already, it would be arbitrary and capricious for EPA not to adjust the PSD regulations to account for the unique characteristics of biogenic CO_2 emissions.

A. Restricting PSD permitting to modifications that result in a significant increase in emissions

The PSD provisions of the CAA literally require a permit for modifications of major stationary sources (through inclusion of modification in the definition of "construction" in CAA section 169(2)(C)), without any limitation on the extent to which the modification results in increased emissions. At the invitation of the *Alabama Power* Court, the EPA promulgated PSD regulations in 1980 that excluded from PSD permitting all modifications, except to the extent that the modification resulted in a significant emissions increase for a pollutant regulated under the Act. *See, e.g.*, 40 C.F.R. § 52.21(b)(2)(i), (23), (39). EPA's justification for that departure from the literal application of the statutory language was that modifications with smaller associated emission increases would have insignificant air quality impacts, and it was an administrative necessity not to require permits for nearly every minor change in a major stationary source. *See, e.g.*, 44 Fed. Reg. 51,924, 51,937-38 (Sept. 5, 1979); 45 Fed. Reg. at 52,705; 75 Fed. Reg. at 31,560 ("EPA has established significance levels for various pollutants, generally relying on a *de minimis* basis....In these actions, EPA generally established the level based on the triviality of the amount of emissions excluded.").

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applicability. *Cf.* 722 F.3d at 419. The dissent objected to that supposed implication because: "If EPA's review shows...that the combustion of certain biomass feedstocks has no effect on – or even reduces – atmospheric CO_2 levels, EPA could then use this information to support a *de minimis* exception to the regulation of certain biogenic CO2 emissions. *Cf. Ala. Power*, 636 F.2d at 330 ('[T]he application of BACT requirements to the emission of all pollutants ... no matter how miniscule ... could impose severe administrative [and economic] burdens.... [T]he proper way to resolve this difficulty is to define a de minimis standard....'). Exempting from regulation a source with a negligible – and particularly, a beneficial – effect on atmospheric CO_2 levels would be perfectly consistent with the overarching PSD and Title V permitting regime – a regime which expressly does not regulate 'minor' sources that cause little harm because they release below-threshold levels of pollutants. *See* 42 U.S.C. §§ 7479(1), 7661(2), 7602(j)." *Id.* at 420.

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EPA derived the significant increase levels by setting them at a small fraction of the emissions that EPA predicted would be necessary for a source to cause an exceedance of the relevant ambient air quality standards. *See* 45 Fed. Reg. at 52,707-708. Note that EPA had to make this determination of *de minimis* impact to support its adoption of the significant increase values applying "reasonable judgment" in "an area in which not only is data limited, but criteria for decision making is almost non-existent." 45 Fed. Reg. at 52,706.

B. Restricting PSD permitting to modifications that result in a significant net emissions increase for the source as a whole

Although the Act does not explicitly authorize it, EPA has, with court approval, defined "major modification" in terms of whether a change results in a significant net emissions increase, taking into account contemporaneous decreases elsewhere at the facility. The D.C. Circuit emphasized that taking this approach, combined with EPA's *de minimis* authority to exclude certain non-significant emissions increases, would "preserve air quality within a framework that allows cost-efficient, flexible planning for industrial expansion and improvement." *Alabama Power*, 636 F.2d at 402; *see also id.* at 400 (EPA's plantwide approach to evaluating a modification provides operating flexibility that "will allow for improvement of plants, technological changes, and replacement of depreciated capital stock."). As described above, the D.C. Circuit also approved EPA's later adoption of a Plantwide Applicability Limit (PAL) approach to assessing whether a modification would result in increased emissions, based on comparison to an emission limitation established for the entire facility, in *New York I*.

C. Restricting BACT and air quality impact analysis requirements to those pollutants for which the new source would have emissions, or the modification would have a net emissions increase, over the pollutant's "significance" level

Although CAA section 165(a)(4) requires that a "proposed facility" required to have a PSD permit must be "subject to the best available control technology for each pollutant subject to regulation under [the Act] emitted from, or which results from, such facility," EPA's PSD regulations have since 1980 only required BACT for each regulated NSR pollutant that a new source would have the potential to emit in "significant amounts," or for which a major modification will result in "a significant net emissions increase at the source." 40 C.F.R. § 52.21(j)(2)-(3). EPA based this exclusion from BACT, for modifications that result in pollutant increases as much as 100 tpy (for criteria pollutants), on its authority to avoid regulation that would result in *de minimis* regulatory benefit, in terms of protecting ambient air quality. *See, e.g.*, 44 Fed. Reg. at 51,937; 48 Fed. Reg. at 38,749 (Aug. 25, 1983). Similarly, although CAA section 165(a)(2)-(3) requires, prior to issuance of a PSD permit, analysis of the effect of the proposed project on ambient air quality, the PSD regulations exempt from the air quality analysis those pollutants that will not be emitted in "significant amounts" (or, for a modification, pollutants for which there will not be a "significant" net emissions increase). 40 C.F.R. § 52.21(m)(1)(*a*)-(*b*); see also 48 Fed. Reg. at 38,749 (explaining how EPA applied the criterion of "significance," as expressed in defined emission rates, to the question of whether a change constitutes a "major modification" requiring a PSD permit and, if so, to whether BACT and air quality analyses will be required for the individual pollutants emitted).

D. Restricting PSD permitting to those pollutants subject to emission limitations under the Act

Section 165 of the CAA, through the definition of "major emitting facility" in section 169, requires a PSD permit for a stationary source that has the potential to emit 250 tons per year (or 100 tons per year for listed categories of sources) of "any air pollutant." Throughout its implementation of the PSD program, however, EPA has *not* determined PSD applicability based on the emissions of anything fitting within the very broad definition of "air pollutant" in CAA section 302(g), but rather has interpreted the use of "any air pollutant" in the PSD provisions of the Act to mean any pollutant subject to regulation under the Act. *See, e.g.*, 54 Fed. Reg. at 27,297. EPA concluded that the statute is ambiguous and that EPA has discretion not to apply PSD applicability criteria to every chemical that meets the definition of "air pollutant," such as "discrete subspecies of criteria pollutants." *Id.* EPA more recently, in the context of applying PSD to GHGs, reaffirmed that interpretation and clarified that a pollutant is "subject to regulation under the Act" if the statute or regulations impose restrictions on its emissions. 75 Fed. Reg. 17,004 (April 2, 2010). As noted above, EPA's reason for limiting PSD applicability in that way, which the Court of Appeals for the D.C. Circuit endorsed, is that substances that fit within the definition of "air pollutant," but whose emissions do not need to be limited to protect public health and welfare, could not have been intended to be subjected to the burden PSD permitting. *See Coalition for Responsible Regulation*, 684 F.3d at 134 ("It is absurd to think that Congress intended to subject stationary sources to the PSD permitting requirements due to emissions of substances that do not 'endanger public health or welfare.'").

E. Excluding certain activities that increase actual or potential emissions from the definition of "modification"

The PSD regulations have, since even before the codification of PSD review in May 1977 CAA Amendments, included a number of exclusions from the definition of "modification," and therefore from the requirement to obtain a PSD permit. For example, a permit is not required for: use of an alternative fuel or raw material that the source is capable of accommodating; an increase in hours of operation or in production rate; use of an alternative fuel derived from municipal solid waste; installation of clean-coal technology; routine maintenance, repair, and replacement; etc. 40 C.F.R. § 52.21(b)(2)(iii); 39 Fe 42,510, 42,514 (1974). In many instances, those exclusions from PSD permitting were justified on the basis of the *de minimis* doctrine. Importantly, EPA in some cases concluded that the circumstances presented *de minimis* regulatory benefit, rather than that the emissions themselves were *de minimis*. *See, e.g.*, EPA's Reply in Support of Its Petition for a Writ of *Certiorari* in *EPA v. State of New York*, S. Ct. No. 06-736, at 7-8 (exclusion based on *de minimis* circumstances is not synonymous with exclusion based on *de minimis* emissions increases); (67 Fed. Reg. 80,290, 80,292-93 (2002) ("routine maintenance" is based on a "case-by-case determination… weighing nature, extent, purpose, frequency, and cost of the work as well as other factors").

F. Excluding certain volatile organic chemicals from PSD permitting, based on their role, over time when mixed with other chemicals in the ambient air, in the formation of ozone

EPA excludes emissions of certain volatile organic compounds ("VOCs") from otherwise applicable PSD permitting requirements. *See* 40 C.F.R. §§ 52.21(b)(2)(ii), 52.21(b)(30), 51.100(s). Despite the fact that these compounds are both "volatile" and "organic" and,

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therefore meet EPA's definition of VOCs, they are excluded from regulation because of their negligible photochemical reactivity. *See* 40 C.F.R. § 51.100(s)(1); 57 Fed. Reg. 3941, 3943-44 (Feb. 3, 1992) (disagreeing with comment that definition exceeded EPA's statutory authority, asserting that "it is *an administrative necessity* and reasonable to define VOC to include all organic compounds except those EPA has determined to be negligibly reactive." (emphasis added)). Notably, EPA has excluded these volatile organics from the PSD permitting program and other CAA regulations not based on an analysis of their direct effects on human health and welfare, but rather based on EPA's determination that they do not, when mixed with other pollutants in the atmosphere and exposed to sunlight, have significant potential to cause the air pollution that EPA is attempting to address through regulation of VOCs: ground-level ozone. *See, e.g.*, 42 Fed. Reg. 35,314 (July 8, 1977) (listing compounds that do not need to be included in regulatory programs addressing ozone air quality, due to their negligible photochemical reactivity); 44 Fed. Reg. 32,042, 32,043 (June 4, 1979) (excluded chemicals "do not appreciably affect ambient ozone levels"); 45 Fed. Reg. 32,424 (May 16, 1980) (compounds to be excluded "are negligibly photochemically reactive and do not appreciably contribute to the formation of ozone. Consequently, controls on emissions of these two compounds would not contribute to the attainment and maintenance of the national ambient air quality standards for ozone."); *id.* (Federal Register notice addresses "the Agency's lack of authority to include in federally approved SIPs controls on substances whose emissions do not contribute, either directly or indirectly, to concentrations of pollutants for which NAAQS have been established under section 109 of the Act."); 69 Fed. Reg. 69,291, 69,292 (Nov. 24, 2004) ("It has been EPA's policy that organic compounds with a negligible level of reactivity need not be regulated to reduce ozone.").

Because EPA does not require ozone SIPs to address the excluded compounds, EPA also concluded that they could not be counted for purposes of the PSD program. As EPA explained in 1983 proposed revisions to its PSD regulations: "The compounds are those that EPA has determined to be negligibly photochemically reactive and hence not precursors of ozone. They are, therefore, not pollutants which are 'subject to regulation under the Act' within the meaning of the PSD and nonattainment regulations." 48 Fed. Reg. at 38,749 (citations omitted). In 1989, EPA codified this long-standing interpretation by promulgating a new definition of "volatile organic compounds" in 40 C.F.R. § 52.21(b)(30). That definition:

> excludes certain organic compounds from the term "VOC" as that term is used in the PSD and nonattainment regulations. The compounds are those that EPA is determined to be negligibly photochemically reactive and, hence, not important precursors of ozone. They are, therefore not considered to be VOCs within the meaning of the PSD and nonattainment regulations. The purpose of the revision is to clarify that increases and decreases in emissions of those compounds are to be ignored completely in any applicability determination with respect to VOCs.

54 Fed. Reg. 27,286, 27,298 (June 28, 1989) (footnote and citations omitted). Note that EPA's exclusion of some volatile organics from regulation as VOCs under PSD and other regulatory programs is not limited only to those chemicals that never contribute appreciably to ground-level ozone formation. For example, in 1994 EPA, exercising its inherent discretion to balance technical considerations in crafting the regulations, excluded from the pollutant VOCs a class of compounds, methyl siloxanes, that in some situations inhibit the formation of tropospheric ozone and therefore have "negative ozone-forming potentials for commonly-occurring ambient

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conditions," but that do form ozone under some anticipated atmospheric conditions. 59 Fed. Reg. 50,693, 50,695 (Oct. 5, 1994).

In some cases, EPA's decision to exclude chemicals from regulation as VOCs has been influenced by other CAA policy goals besides just maintaining compliance with ozone ambient standards. *See* 54 Fed. Reg. 1987 (Jan. 18, 1989) (acting to exclude chemicals from the definition of VOCs in part in order to facilitate substitution of those chemicals in industrial processes because they have lower potential to degrade the stratospheric ozone layer). *See also* 77 Fed. Reg. 37,610, 37,611 (June 22, 2012) ("It has been the EPA's policy that organic compounds with a negligible level of reactivity should be excluded from the regulatory VOC definition so as to focus VOC control efforts on compounds that do significantly increase ozone concentrations. The EPA also believes that exempting such compounds creates an incentive for industry to use negligibly reactive compounds in place of more highly reactive compounds that are regulated as VOCs."). Encouraging substitution of solvents with lower toxicity also has played a role in EPA's determinations of which chemicals to include in the pollutant VOCs. *See, e.g.*, 42 Fed. Reg. 35,314 (July 8, 1977) (declining to exclude from VOCs some compounds which have only negligible photochemical reactivity but are carcinogenic, etc.); 59 Fed. Reg. 49,877, 49,881 (Sept. 30, 1994); 59 Fed. Reg. at 50,695 ("adding these compounds to the list of negligibly-reactive VOC may provide support for the EPA's pollution prevention efforts").

G. Imposing different PSD applicability thresholds for different sizes of particulate matter, based on relative effects resulting from their presence in the ambient air

EPA has distinguished among different categories of particulate matter ("PM") based on differences in environmental and public health impacts. *See Alabama Power*, 636 F.2d at 369 n.131 ("EPA has discretion to define the pollutant termed 'particulate matter' to exclude particulates of a size or composition determined not to present substantial public health or welfare concerns."). EPA has distinguished between fine and coarse PM and established distinct significance levels for total particulate matter, particulate matter smaller than 10 microns in diameter, and particulate matter smaller than 2.5 microns in diameter (fine particulate), based on the particle size's impact on public health. *See* 40 C.F.R. § 52.21(b)(23)(i). Thus, a modification may result in 2 ½ times as much emissions of coarse particulate matter than fine particulate matter without triggering PSD permitting.[35]

H. Excluding certain greenhouse gases from the regulated pollutant GHGs, based on relative contribution, in the well-mixed global atmosphere, to global warming

EPA already has used the discretion available to it in implementing the PSD provisions of the CAA to limit the GHGs that are subject to permitting requirements. In the Tailoring Rule and other GHG regulations, EPA exercised its discretion to limit the applicability of its GHG regulations by narrowly defining the pollutants that qualify as "greenhouse gases." EPA chose to limit its definition of "greenhouse gases" to "the aggregate group of six" specified chemicals, excluding other chemicals that also have climate impacts. *See* 75 Fed. Reg. 25,324, 25,397 (May 7, 2010) (identifying the six compounds as "the primary greenhouse gases of concern"); *id.* at 25,398-99 (describing light-duty vehicle emissions standards as regulating "the single air

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[35] Similarly, EPA concluded that it had the flexibility to adopt PSD "increments" for particulate matter less than 2.5 micrometers in diameter, even though the Clean Air Act only provides increments for total suspended particulate matter and authorizes EPA to substitute increments for particulate matter smaller than 10 micrometers. *See* CAA sections 163(b), 166(f); 75 Fed. Reg. 64,864 (October 20, 2010).

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pollutant" constituting the aggregate of the six identified gases). EPA limited the pollutant GHG to these six compounds despite its findings that they only account for 75% of total anthropogenic heating. 74 Fed. Reg. 66,496, 66,517, 66,520 (Dec. 15, 2009) (excluding other gases because they are not thought to be the key drivers of radiative heating, or are not as studied and well-understood as the six listed compounds). EPA asserted that "Congress provided EPA broad discretion to determine appropriate combinations of compounds that should be treated as a single air pollutant." 74 Fed. Reg. at 66,537. *See also id.* at nn.35-36 (EPA has authority to treat a group of compounds, or even a combination of groups of compounds, as an "air pollutant" to be regulated under the CAA, and has done so in the past).

I. Establishing different PSD applicability thresholds for GHGs than for other pollutants, based in part on the impact that those GHG emissions have, in the global atmosphere over time, on the potential for global warming

In the Tailoring Rule and other GHG regulations, EPA invoked a series of administrative law doctrines to increase the emissions thresholds for GHGs that are orders of magnitude greater than those for other pollutants regulated under the PSD program. *See, e.g.,* 75 Fed. Reg. at 31,533 (describing EPA's authority "to depart[] from a literal interpretation of statutory provisions"). EPA asserted that as a matter of administrative necessity and to avoid absurd results contrary to clear congressional intent, it was necessary to exclude thousands of small sources from PSD permitting that would apply if the statutory thresholds for "major stationary sources" were applied to GHG emissions. *See, e.g., id.* at 31,557-58. Although EPA, in litigation over the Tailoring Rule, disclaimed reliance on the *de minimis* doctrine, in fact part of EPA's statement of the basis for the Tailoring Rule reflects EPA's assessment that imposing PSD permitting on smaller sources of GHGs would not significantly further the regulatory goal of reducing the air pollution of excessive GHGs in the global atmosphere. *See, e.g., id.* at 31,557 ("Moreover, at the present time, there is relatively little environmental benefit in subjecting large numbers of small GHG sources to the expensive, source-by-source PSD permitting requirements."); *see also id.* at 31,531 (limiting PSD permitting to sources emitting more than 100,000 tpy CO_2e would assure that the PSD program addressed "sources and modifications that have the greatest impact on radiative forcing of the GHGs emitted").

J. Establishing differentiated PSD applicability thresholds for the compounds that make up the air pollutant "greenhouse gases," based on the impact that emissions of each compound is expected to have, once well-mixed in the global atmosphere and over time, on the potential for global warming

In the Tailoring Rule, EPA based PSD applicability for GHG emissions on an artificial, calculated emission rate – carbon dioxide equivalents ("CO_2e") – that takes into account the varied global warming potentials ("GWP") of different components of the regulated pollutant "greenhouse gases." *See* 40 C.F.R. §§ 52.21(b)(49)(ii)-(v); 75 Fed. Reg. at 31,522. Thus, under current PSD regulations a new source could emit 25 times more CO_2 without obtaining a PSD permit than it could methane. *See* 40 C.F.R. §§ 52.21(b)(49)(ii) and 40 C.F.R. pt. 98 subpt. A Table A-1. This deviation from a literal application of the statutory PSD provisions is not based on EPA's GHG regulations for light-duty vehicles, since those rules set separate emission standards for CO_2, methane, and nitrous oxide, and do not involve aggregating emissions of the three compounds or applying weighting factors. *See* 75 Fed. Reg. at 25,421. Rather, EPA implemented the GWP weighting factors specifically for determining whether a new or modified

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stationary source will require a PSD permit, in recognition that emissions of the same annual quantity of different "greenhouse gases" can have very different potential impacts on climate change.[36] *See* 75 Fed. Reg. at 31,531 (using CO_2e, which incorporates global warming potential weighting factors, for determining PSD applicability "best addresses the relevant environmental endpoint"); *id.* at 31,531-32 (rejecting comment that EPA has no discretion to depart from actual annual mass emissions in determining PSD applicability).

V.   **Excluding certain biogenic CO_2 emissions from PSD permitting would be within EPA's discretion in implementing the PSD program and would be consistent with prior EPA actions.**

As explained in Part II above, there are important policy imperatives supporting differentiated treatment of biogenic CO_2 emissions for PSD permitting purposes. EPA has the discretion to do so under the CAA and judicial interpretations of EPA's PSD rulemaking authority, and distinguishing biomass combustion in the PSD regulations would be consistent with past EPA actions exercising that authority.

If the current deferral of application of PSD permitting to emissions from biomass is vacated or expires, and EPA fails to promulgate PSD applicability regulations that differentiate between biogenic CO_2 emissions and CO_2 emissions from fossil fuels, projects that will not result in higher concentrations of GHGs in the global atmosphere – the identified harm that EPA is trying to mitigate – will be subject to lengthy and costly delays associated with PSD permitting. As explained in Part II, because the efficiency of generating thermal energy with biomass generally will be less than for fossil fuel, PSD rules that treat biogenic CO_2 emissions the same as CO_2 emissions from burning fossil fuel can mean that choosing to use fossil fuel, or choosing not to switch from fossil fuel to biomass, may allow a source to avoid costs and delays associated with PSD permitting. Permitting rules that discourage and delay the use of residuals for fuel may result in greater contribution of GHGs to the atmosphere from the decomposition of unused residuals, and permitting rules that impose higher burdens on biomass-fueled projects than fossil-fueled ones have an effect on the value of biomass that can, on the margin, discourage private landowners from maintaining and increasing forested lands.

Failure to differentiate between biogenic CO_2 emission sources and fossil fuel emission sources not only imposes regulatory burdens on use of biomass that are not justified in terms of the minimal regulatory benefit, but also creates, in practice, a disincentive for use of biomass and for maintaining lands in forest use, which EPA should be encouraging. EPA can and should recognize that the growth and maintenance of biomass stocks in the United States has a substantial positive effect on the air pollution EPA is seeking to address through regulation of GHGs. Harvesting of biomass and its use for energy production is part of the overall favorable flow of carbon stocks, and not a withdrawal from carbon stocks such as occurs from combustion of fossil fuels. EPA has substantial discretion to define the PSD program in a way that recognizes that reality. EPA cannot and should not impose regulatory burdens on biomass use that will result in little if any improvement in the buildup of excessive concentrations of GHGs in the global atmosphere. EPA is authorized and indeed required to consider the congressional goal

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[36] EPA's use of CO_2e and GWP is consistent with EPA's practice under the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks* and with international practice under the Intergovernmental Panel on Climate Change.

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of not unduly interfering with economic development when it fashions the PSD program to reflect the new and unique circumstances GHGs, and biogenic GHGs in particular. See pp. 18-19, 20-22, 27, *supra*.

Whether viewed as exercising its discretion to interpret ambiguous statutory requirements, see pp. 17-18, *supra*, employing its inherent authority to avoid imposing regulatory burdens where there will be little or no regulatory benefit, see pp. 18-21, *supra*, or relying on administrative necessity to avoid regulations that are contrary to the purposes of the statute, see p. 21-22, *supra*, EPA has authority to exclude biogenic CO_2 emissions from PSD applicability determinations and from the requirement to implement BACT, in light of the distinctly different impact that activities using biomass have on the build-up of excessive GHG emissions in the global atmosphere. To recognize that the use of certain biomass fuels or raw materials does not contribute significantly to the concentration of greenhouse gases in the global atmosphere, and to avoid regulating such biogenic emissions so as to prevent unnecessary or even counterproductive regulatory burdens, EPA should adopt amendments to the PSD permitting regulations that are clear and predictable in their application and not unduly burdensome for permitting authorities, permit applicants, or the biomass suppliers (e.g., forest landowners, biomass residual fuel brokers, etc.).[37]

The case for such regulatory exclusions is particularly clear with respect to emissions of CO_2 from forest products manufacturing residuals. Because burning of forest products manufacturing residuals has the effect of eliminating "anyway emissions" associated with that material, which emissions would have a greater contribution to potential global warming than the GHG emissions that occur when the residuals are burned, it would be inconsistent with the purposes of the CAA to subject the burning of forest products manufacturing residuals for energy recovery to the PSD program, since the purpose of requiring PSD permitting for GHGs is to mitigate the "air pollution" EPA is addressing, namely the build-up of excessive concentrations of GHGs in the global atmosphere leading to global warming. Excluding CO_2 emissions associated with combustion of forest products manufacturing residuals for energy recovery thus is a reasonable interpretation of the PSD provisions of the CAA, including the definitions of "emissions" and "modification." It is analogous, for example, to EPA's exclusion of methyl siloxanes from regulation as VOCs because under many circumstances they have an ameliorative effect on the "air pollution" at issue: excessive ozone concentrations in the ground-level atmosphere. See pp. 28-30, *supra*.

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[37] Biogenic CO_2 emissions that do not contribute significantly to the concentration of greenhouse gases in the global atmosphere should not be counted in determining whether a source exceeds the threshold to be considered a "major stationary source," or whether a major stationary source is making a modification that exceeds the thresholds to be considered a "major modification," triggering the requirement to obtain a PSD permit before commencing construction of the new source or modification. In addition, the regulations need to make clear that, if a project is required to obtain a PSD permit anyway, because of emissions of criteria pollutants or of other, non-excluded GHGs, BACT will not be required for the project's biogenic CO_2 emissions. Otherwise, a BACT determination – with attendant delay, uncertainty, and cost – might be required for the project's biogenic CO_2 emissions of any amount. EPA acknowledged the necessity of applying such a significance level in determining applicability of BACT to biogenic CO_2 emissions, "which, in effect, is a BACT threshold." 75 Fed. Reg. at 31,567-68. The PSD regulations have for decades exempted from BACT review those pollutants for which the emissions increase from a project would be less than specified significance levels. *See* 40 C.F.R. §§ 52.21(j)(2) – (3).

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Likewise, such an exclusion would be well within EPA's demonstrated capability to exclude from PSD requirements projects that result in a net emissions increase from a facility less than defined "significant increase" levels. See pp. 19, 26-27 , *supra*. While those regulations exempt emissions of tens of tons a year, because they are not predicted to have a substantial adverse effect on ambient air quality, in the case of CO_2 emissions from burning forest products manufacturing residuals the overall net effect on air quality – expressed as the buildup of excessive concentrations GHGs in the global atmosphere, with the resulting potential for global warming – is actually beneficial. See pp. 11-12, *supra*. A categorical exclusion from PSD permitting for emissions of CO_2 from forest products manufacturing residuals is thus squarely within the EPA's well-established authority to avoid literal application of statutory requirements where the avoided regulatory burden would have produced little or no regulatory benefit. See pp. 18-22, *supra*.[38]

Excluding CO_2 emissions associated with combustion of forest products manufacturing residuals for energy recovery from PSD applicability and BACT requirements also is authorized under the doctrine of administrative necessity and to avoid absurd results. As with EPA's exemption of smaller GHG emission sources in the Tailoring Rule, exempting forest products manufacturing residuals from PSD will assure that limited permitting resources are focused on new and modified sources whose construction will add to the excessive buildup of GHGs in the global atmosphere. See pp. 31-32 *supra*. Since imposing PSD requirements on CO_2 emissions from forest products manufacturing residuals would have the perverse effect of encouraging sources to dispose of forest products manufacturing residuals instead of making the investment to burn them for energy recovery, and to burn fossil fuel instead of forest products manufacturing residuals, leading to an increase in the global warming potential of GHGs in the global atmosphere, the absurd results doctrine justifies EPA's exclusion of CO_2 emissions from forest products manufacturing residuals combustion from PSD applicability. In that way, a categorical exclusion from PSD permitting for forest products manufacturing residuals combustion sources is analogous to many previous EPA actions limiting the scope of the PSD program, such as establishing significance levels to assure that the PSD program does not unnecessarily interfere with plant improvements and innovations (see pp. 26-27, *supra*); determining whether a major modification has occurred based on net emissions from the entire plant (see p. 17-18, 27, *supra*); applying higher PSD applicability thresholds for GHGs than for typical pollutants emitted in much lower amounts (see pp. 24-25, 31-32, *supra*); and treating different chemicals contributing

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[38] Exemption of CO_2 emissions from combustion of forest products manufacturing residuals because there would be little or no regulatory benefit would be very different from the adoption of an SMC for $PM_{2.5}$, which the D.C. Circuit struck down in *Sierra Club v. EPA*, 705 F.3d 458 (*See* pp. 24-25, *supra*). Here, EPA would not be weighing whether the burdens of applying PSD permitting to CO_2 emissions from combustion of forest products manufacturing residuals exceed the benefits. *Cf. id.* at 469. Rather, EPA would be determining that there would be little or no regulatory benefit, and in fact it would in most cases be damaging to the regulatory purpose of applying PSD to GHGs, if PSD permits were required for CO_2 emissions from combustion of forest products manufacturing residuals. The CAA does not contain any statement that biogenic CO_2 emissions must be subjected to PSD permitting, nor does it contain certain exceptions that imply Congress did not intend an exception for biogenic CO_2. *Cf. id.* at 467-68. EPA already has concluded in numerous rulemakings that the statutory terms are ambiguous enough to allow it to exempt small sources of criteria pollutants, GHG emissions with lower global warming potential, and so forth from PSD permitting. Differentiating CO_2 emissions from combustion of forest products manufacturing residuals in PSD applicability regulations would be entirely consistent with *Alabama Power*'s discussion of EPA's *de minimis* authority, which the *Sierra Club* Court embraced.

to the pollutant GHGs differently for PSD applicability purposes because of the great discrepancies in their potential contribution to global warming (see p. 31-32, *supra*).

Given the substantial discretion that EPA has in implementing the PSD program, as explained in Part III above, and the fact that excluding CO_2 emissions from combustion of forest products manufacturing residuals would have an overall beneficial impact on the air pollution that EPA is attempting to address through regulation of GHGs, EPA would be entirely justified in promulgating amendments to the PSD regulations that would create such an exclusion. In fact, under the circumstances, and especially in light of EPA's exercise of its discretion to create numerous other exemptions to PSD applicability in past rulemakings, it would be arbitrary and capricious for EPA not to do so with respect to CO_2 emissions from forest products manufacturing residuals. *See, e.g., Transactive Corp. v. U.S.*, 91 F.3d 232, 237 (D.C. Circ. 1996) ("A long line of precedent has established that an agency action is arbitrary when the agency offered insufficient reasons for treating similar situations differently." (citations omitted)).

In considering how to apply PSD to biogenic CO_2 emissions from forest products manufacturing residuals and from other types of biomass, it also is appropriate for EPA to consider the benefits, in terms of advancing other important policy objectives, unrelated to the PSD program, that removing disincentives for the use of biomass as an energy source would produce. EPA has authority to apply such considerations in determining, for example, whether the regulatory benefits would be *de minimis* or whether an adjustment in applicability is an administrative necessity, and EPA has done so in the past with respect to numerous exclusions from PSD applicability. See pp. 18-26, and 26-32, *supra*. As explained in Part II above, those policies strongly favor PSD regulations that facilitate, rather than discourage, use of biomass as a fuel.

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NATIONAL COUNCIL FOR AIR AND STREAM IMPROVEMENT

GREENHOUSE GAS AND FOSSIL FUEL

REDUCTION BENEFITS OF USING

BIOMASS MANUFACTURING RESIDUALS

FOR ENERGY PRODUCTION IN

FOREST PRODUCTS FACILITIES

TECHNICAL BULLETIN NO. 1016

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PRESIDENT'S NOTE

NCASI continues its work to address the United States Environmental Protection Agency's expressed interest in the life cycle greenhouse gas benefits associated with using biomass. The regulatory decisions EPA makes on this topic have the potential to greatly affect the costs of doing business and the perception of the forest industry's products in the marketplace. The forest products industry, therefore, has a great deal at stake in ensuring that the agency's deliberations on this topic are well informed.

In an earlier report, NCASI examined the life cycle greenhouse gas and non-renewable energy benefits of using black liquor in the kraft recovery system. In the study described herein, NCASI extends this work to other types of biomass-based manufacturing residuals used for energy generation within the industry. While there are numerous studies examining the life cycle impacts of biomass energy, none has applied the comprehensive approach used here by NCASI to characterize the impacts of the industry's use of energy produced from biomass residuals.

In this study, NCASI has compared systems involving the use of biomass-based manufacturing residuals for energy to comparable systems relying on fossil fuels. The results indicate that the industry's use of these manufacturing residuals for energy avoids the release of approximately 110 million metric tons of CO_2E per year.

Combining the results of this study with the results of the previous NCASI study on black liquor reveals that each year's use of biomass-based manufacturing residuals (including black liquor) in the US forest products industry avoids the emission of approximately 218 million metric tons of CO_2E, an amount more than three times the annual direct emissions of CO_2 from fossil fuel combustion in the industry.

This study is one of a series of ongoing NCASI projects having the objective of helping the forest products industry and its stakeholders better understand the greenhouse gas and energy impacts of using forest biomass as a raw material and fuel.

Ronald A. Yeske

October 2013

GREENHOUSE GAS AND FOSSIL FUEL REDUCTION BENEFITS OF USING BIOMASS MANUFACTURING RESIDUALS FOR ENERGY PRODUCTION IN FOREST PRODUCTS FACILITIES

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ABSTRACT

This study examined the life cycle greenhouse gas (GHG) and fossil fuel-related benefits of using various biomass residuals for energy production within the forest products industry, including pulp and paper mills and wood products manufacturing facilities. More specifically, woody mill residuals (e.g., bark, sawdust, etc.), wastewater treatment plant residuals, and paper recycling residuals (i.e., materials removed during processing of recovered fiber to eliminate contaminants and yield reusable fiber) were studied. Two product systems were compared: a product system in which the biomass residuals are burned for energy in a forest products industry facility (biomass energy system), and a product system in which the biomass residuals are disposed of and fossil fuels are used instead to generate an identical amount and form of energy (non-use system). For each residual type, various scenarios were evaluated, including one (the typical scenario) that best represents the industry average. Moreover, a variety of residual characteristics were subjected to sensitivity analyses.

For all residuals studied, except paper recycling residuals, the system using residuals for energy produced GHG emissions, not including biogenic CO_2, that were generally 98% lower than those from the system disposing of the residuals instead of using them for energy. Paper recycling residuals resulted in significant but lower benefits because they are comprised of a portion of plastic. Even when biogenic CO_2 was included in the analysis, the GHG emissions for typical scenarios regarding a) woody mill residuals, b) wastewater treatment plant residuals, and c) paper recycling residuals were lower in the biomass energy systems by 261 kg CO_2E/GJ, 295 kg CO_2E/GJ and 112 kg CO_2E/GJ, respectively when compared to the non-use systems. Compared to the analogous fossil fuel-based systems, fossil fuel consumption was found to be lower by more than 99% for all residuals examined in this study. The benefits of using biomass residuals for energy production start to be seen in less than one year under typical scenarios. An analysis that addressed the fate of the biogenic carbon, not considering fossil fuels substitution benefits, was also performed which showed that benefits from using residuals for energy, including black liquor, start to be achieved in 0 to 7.7 years, with a weighted average of 2.4 years.

The current annual use of the manufacturing residuals examined in this report avoids the release, over time, of approximately 110 million tonnes of CO_2E. Combining the results of this study with the results of the previous NCASI study on black liquor reveals that each year's use of biomass-based manufacturing residuals (including black liquor) in the US forest products industry avoids the emission of approximately 218 million tonnes of CO_2E, which is more than three times the annual direct emissions of CO_2 from fossil fuel combustion in the industry.

KEYWORDS

biomass residuals, energy, greenhouse gases, life cycle assessment

RELATED NCASI PUBLICATIONS

Technical Bulletin No. 984 (April 2011). *Greenhouse gas and non-renewable energy benefits of black liquor recovery.*

GREENHOUSE GAS AND FOSSIL FUEL REDUCTION BENEFITS OF USING BIOMASS MANUFACTURING RESIDUALS FOR ENERGY PRODUCTION IN FOREST PRODUCTS FACILITIES

TECHNICAL BULLETIN NO. 1016
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EXECUTIVE SUMMARY

Wood handling and processing activities in log yards, sawmills, pulp and paper mills, and other forest products activities produce a significant amount of residuals, most of which consist of black liquor, bark, sawdust, shavings, and other woody debris. These currently available residuals are increasingly being used as a source of renewable energy.

There have been a rapidly increasing number of life cycle assessment (LCA) studies of energy produced from woody biomass. Studies have mainly focused on electricity generation and district heating. In those instances where studies have addressed the use of woody biomass residuals by forest products facilities (e.g., sawmills), they typically have not considered alternative fates for the residuals. In addition, while not traditionally considered in typical LCA studies, the timing of emissions may be an important consideration in some contexts.

ES.1   Objective

The overall objective of this study was to evaluate the life cycle (cradle-to-final energy analysis) greenhouse gas (GHG) and fossil fuel reduction benefits of using various forms of forest biomass residuals (manufacturing-related) for energy production in forest products manufacturing facilities in contrast to no beneficial use of these residuals coupled with production of the same quantity and form of energy using fossil fuels. This study supplements a previous NCASI study that analyzed the greenhouse gas reduction benefits of using spent pulping liquor, known as black liquor, for energy in the forest products industry, for which the results are also summarized in this study to present a comprehensive picture of the benefits of the industry's use of forest biomass residuals for energy production.

This study also included two secondary objectives: 1) to analyze the emissions of biogenic greenhouse gases (GHGs) directly released from the units in which the residuals are managed (i.e., combustion units or landfills, also called a gate-to-gate analysis) and 2) to analyze the annual/cumulative emissions attributable to the use of the residuals for energy as an ongoing, long-standing practice (both in terms of cradle-to-final energy and gate-to-gate boundaries).

The biomass residuals specifically studied in this project were

- woody mill residuals (e.g., bark, sawdust and other similar manufacturing residuals from sawmills, panel plants, and pulp and paper mills);
- wastewater treatment plant (WWTP) residuals; and
- paper recycling residuals (e.g., old corrugated container (OCC) rejects)[1].

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[1] Paper recycling residuals are materials removed during processing to eliminate contaminants and yield reusable fiber. They generally consist of a fiber and plastic fraction.

ES.2   Methods

ES.2.1 Methods for the Cradle-to-Final Energy Analysis

For each type of residual, the study compared two different product systems:

1) one in which the biomass residuals are burned for energy (**biomass energy system**); and
2) one in which the biomass residuals are disposed of and fossil fuels are used instead to generate an identical amount and form of energy (**non-use system**).

More specifically, the methodology used in this study followed life cycle principles by calculating emissions from "cradle to final energy," including fuel conversion efficiency. The primary functional unit employed in this study was *the production of 1 GJ of energy*. It is important to note that whether manufacturing residuals are used for energy or disposed of, the same number of trees would be harvested and the same quantity of resources would be required to produce the related forest products.

The overall analysis approach employed in this study is as follows. First, for each system component of the study (size reduction, biomass energy production, alternative fate of the residuals and fossil fuel displaced), several scenarios were defined. These scenarios were intended to represent a broad range of conditions in the US forest products industry. Then, a typical scenario was defined for each residual type representing the best estimate of average conditions in the US in terms of the system components mentioned above. The typical scenario was analyzed to determine 1) typical benefits obtained by using a given residual type, 2) the contribution of each different system component to the overall results, 3) the sensitivity of various parameters (i.e., biomass properties such as higher heating value, water content, etc.) to the results, and 4) the timing of emissions. Where possible, each parameter was analyzed using a base case, low, and high value. Finally, a number of system configuration scenarios were also analyzed.

The difference in greenhouse gas impact (GHGI) between product systems was determined by calculating the differences in annual GHG emissions from the systems and determining the cumulative radiative forcing impacts associated with these differences over time, out to 100 years. The difference in GHGI between the two systems was calculated twice, once with biogenic CO_2 included in the analysis and once with biogenic CO_2 excluded. In addition to characterizing the total difference in GHGI over 100 years, this study examined the implications of using biomass residuals for energy as a function of time. When residuals are burned for energy, the biogenic carbon is immediately released to the atmosphere. In contrast, residuals placed into landfills degrade and release the carbon over time.[2] In such cases, the emissions from the biomass energy system could sometimes be higher in the short term than those from the non-use system, but the emissions from the non-use system overtake those from the biomass energy system relatively quickly. For each residual, this study computed the number of years required for the cumulative radiative forcing associated with the emissions from the non-use system to equal the cumulative radiative forcing associated with the emissions from the biomass energy system (referred to as the "break-even time" in this report). After

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[2] The results of an earlier study of the benefits of using black liquor are also included in this report. For black liquor, it is difficult to construct an alternative fate scenario because the material is integral to pulp production. Nonetheless, in the earlier study it was assumed that, if not used in the kraft recovery cycle, black liquor would be incinerated or treated in aerobic wastewater treatment plants. In both cases, the carbon returns to the atmosphere far too rapidly for carbon storage to be important in the calculations. It was assumed that all carbon is emitted as biogenic CO_2. If, however, some of the carbon was emitted as methane, the benefits of using the liquor in the kraft recovery cycle would be greater than estimated in the previous study.

this point, the cumulative radiative forcing associated with the non-use system remains higher than that associated with the biomass energy system for the remainder of the 100-year period. Dynamic calculations of cumulative radiative forcing were used in the analysis rather than conventional global warming potentials because the intent was to capture the time-dependent impacts of each system, which is not possible using global warming potentials which assess cumulative radiative forcing over a single period (e.g., 100 years).

The difference in fossil fuel consumption between the two systems use was also calculated.

ES.2.2 Methods for Additional Analyses

In addition to the life cycle analyses described above, two secondary analyses were undertaken.

The first involved limiting the analysis to the fate of the biomass carbon, without regard to fossil fuel substitution benefits. In this analysis, the two compared systems (i.e., the biomass energy system and the non-use system) have been compared in terms of the emissions coming directly out of the units receiving the residuals (i.e., combustion units or landfills). In the case of paper recycling residuals, only the fiber fraction was considered as the focus here was on the fate of the biomass carbon. The results were computed for two indicators: difference in GHGI over 100 years and break-even time.

The second analysis consisted of changing the frame of analysis to evaluate the annual/cumulative emissions attributable to the ongoing use of the residuals. For this analysis, a different functional unit was used, defined as *the yearly production of 1 GJ of energy as an ongoing practice*. The differential GHGI indicator was computed on a yearly basis so as to estimate when in the past the practice would have had to begin in order for the difference in GHGI to become zero in 2014. These results were computed both for the full life cycle (i.e., including fossil fuel substitution) and for the more constrained analysis looking only at the biogenic GHG emissions from the units receiving the residuals.

ES.3 Results from the Cradle-to-Final Energy Analysis, Including the Benefits of Displacing Fossil Fuels

ES.3.1 Difference in GHGI, Including Biogenic CO_2

Table ES.1 summarizes the differences in life cycle GHG impact, over 100 years, between the systems using residuals for energy and the systems using fossil fuels when biogenic CO_2 is included in the emissions. The negative values in this table indicate that the biomass energy system produced less impact than the non-use system. When considering a weighted average of all residuals used by the industry, including black liquor, the biomass energy systems produced an emissions impact that was lower by 208 kg CO_2E/GJ when compared to the non-use systems. Given current practice, this means that the use of manufacturing residuals (including black liquor) in the industry for one year avoids approximately 218 million tonnes CO_2E, which is more than three times the annual direct emissions (Scope 1) associated with the combustion of fossil fuels in the forest products industry.

The reduction occurs across a range of system configuration scenarios (boiler type, assumptions about the displaced fossil fuel, the GHG intensity of the electricity grid, and the level of cogeneration at forest products facilities) and without affecting the amount of wood harvested or the amount of forest products produced.

Table ES.1 Difference in Total Life Cycle GHG Emissions (including Biogenic CO_2):
Biomass Energy System Compared to Comparable Fossil Fuel-Based System
Where the Residuals are Disposed

Residual Type	Differential GHGI: Difference in Emissions Impact for Typical Scenario (kg CO_2E/GJ)
Woody mill residuals	-261
WWTP residuals	-295
Paper recycling residuals	-112
Black liquor	-182
Weighted average of biomass manufacturing residuals	-208

ES.3.2 Relative Difference in GHGI, Excluding Biogenic CO_2

Table ES.2 summarizes the differences in life cycle GHG emissions impacts, over 100 years, between the systems using residuals for energy and the systems using fossil fuels when biogenic CO_2 is excluded from the life cycle emissions. The negative results in this table indicate that the biomass energy system produces a smaller greenhouse gas impact than the non-use system. Using woody mill residuals and WWTP residuals for energy produces a reduction in impact from non-biogenic CO_2 GHGs of at least 98% compared to the non-use systems, across all system configuration scenarios and sensitivity analyses. Paper recycling residuals also result in significant, but lower, benefits (86.4% reduction in the typical scenario) mainly because these residuals are comprised of a portion of plastic. The previous study of black liquor by NCASI showed emissions of non-biogenic CO_2 GHGs that were lower by 90.5% for a system using black liquor in the kraft recovery system compared to a comparable system based on fossil fuels. When considering a weighted average of all manufacturing residuals used by the industry under their typical scenarios, including black liquor, the biomass energy system produced an emissions impact attributable to non-biogenic CO_2 GHGs that was 93.3% lower than those from the defined non-use system.

Table ES.2 Life Cycle GHG Emissions, Not Including Biogenic CO_2: Percent Difference
in GHG Impact between the Biomass-Based System and the Comparable Fossil Fuel-Based System
Where the Residuals are Disposed

Residual Type	Relative GHGI: Difference in Typical Scenarios (%)
Woody mill residuals	-99.1
WWTP residuals	-98.7
Paper recycling residuals	-86.4
Black liquor	-90.5
Weighted average of biomass manufacturing residuals	-93.3

ES.3.3 Emissions Timing

While not traditionally considered in LCA studies, the timing of emissions can be an important consideration for certain policy discussion/design contexts. When residuals are burned for energy, the biogenic carbon is immediately released to the atmosphere. In contrast, residuals placed into landfills release carbon over time. This delay is one of the reasons why forest biomass energy systems can

initially emit more GHGs than the corresponding fossil fuel systems which dispose of the residuals. In a relatively short period, however, the cumulative radiative forcing associated with emissions from the fossil fuel systems becomes greater than that from the corresponding biomass systems due to the GHGs (including methane) produced by the decaying residuals and the GHG emissions from fossil fuel combustion. An assessment performed to address the timing of benefits produced the results summarized in Table ES.3. The results indicate that, when fossil fuel substitution is considered, it takes less than one year for the cumulative radiative forcing associated with the biomass energy system to be less than that associated with the non-use system.

Table ES.3 Time for Biomass Energy Systems to Have Lower Cumulative Radiative Forcing from GHG Emissions (Including Biogenic CO_2) Than the Corresponding Non-Use Systems

Residual Type	Break-Even Time: Typical Scenarios (years)
Woody mill residuals	0.6
WWTP residuals	0
Paper recycling residuals	0
Black liquor	0
Weighted average of biomass manufacturing residuals	0.2

ES.3.4 Fossil Fuel Consumption

Table ES.4 summarizes the results obtained for the Fossil Fuel Consumption indicator. The negative values in this table indicate that the biomass energy systems use less fossil fuel than the corresponding non-use systems. For all residual types analyzed in this report, considering all system configuration scenarios and sensitivity analyses performed, it was shown that fossil fuel consumption was lower by more than 98% in the biomass energy systems compared to the non-use systems. Note that a previous study by NCASI showed 89.8% lower fossil fuel consumption for a system using black liquor when compared to a scenario based on fossil fuel. When considering a weighted average of all residuals used by the industry, including black liquor, the biomass energy systems used 93% less fossil fuel when compared to the defined non-use system.

Table ES.4 Fossil Fuel Consumption: Percent Difference between the Biomass-Based Systems and the Comparable Fossil Fuel-Based Systems Where the Residuals are Disposed

Residual type	Relative Fossil Fuel Consumption: Difference in Typical Scenarios (%)
Woody mill residuals	-100
WWTP residuals	-99.3
Paper recycling residuals*	-99.9
Black liquor	-89.8
Weighted average of biomass manufacturing residuals	-93.1

*Considering that the plastic fraction of paper recycling residuals is not a new input of fossil fuel.

ES.4   Results from Additional Analyses

ES.4.1 Analysis of Biogenic GHGs, Ignoring Fossil Fuel Displacement (Gate-to-Gate Analysis)

All the results presented above were computed using a life cycle approach that considered the fossil fuels being displaced by biomass residuals. The typical scenarios for the two product systems (i.e., one system using residuals for energy and the other system managing the residuals by some other means) have also been compared in terms of the emissions coming directly out of the units receiving the residuals (i.e., combustion units or landfills). In this analysis, the benefits of fossil fuel substitution were ignored.

As shown in Table ES.5, even in this highly constrained analysis, using the biomass residuals for energy generation resulted in significantly lower GHG impact. A significant fraction of the emissions benefits were attributable to avoidance of landfill methane. A previous, similarly constrained analysis on black liquor assumed that the alternative management scenario would almost certainly involve returning the biogenic carbon in the liquor to the atmosphere. To be conservative, it was assumed in that study that the carbon would return to the atmosphere as CO_2 via incineration or treatment in aerobic wastewater treatment plants. This resulted in net zero biogenic GHG releases for energy production compared to an alternative fate. The reduction in biogenic GHG emissions impact over 100 years associated with the use of all manufacturing residuals (weighted according to usage), including black liquor, was shown to be 51 kg CO_2E/GJ.

When the benefits of fossil fuel displacement are ignored, it takes longer for the biomass energy systems to arrive at the point where cumulative radiative forcing is lower than for the corresponding non-use systems. Considering only biogenic emissions, the biomass energy systems required from 0 to 7.7 years, with a weighted average of 2.4 years for typical scenarios (including black liquor), to produce lower cumulative radiative forcing.

Table ES.5 Results of Analysis of Biogenic GHGs, Ignoring Fossil Fuel Displacement

Residual Type	Difference in Biogenic GHGI (kg CO_2E/GJ)	Break-Even Time (years)
Woody mill residuals	-154	7.4
WWTP residuals	-190	5.9
Fiber fraction of paper recycling residuals*	-132	7.7
Black liquor	0	0
Weighted average of manufacturing residuals	-51.1	2.4

* In addition to biomass, paper recycling residuals contain plastics which are produced from fossil fuels. For the purpose of the biomass carbon fate analysis, only the biomass fraction was considered.

ES.4.2 GHG Emissions from Ongoing Use of Residuals for Energy Production

The analysis above examined the impact over time associated with producing 1 GJ of energy on a one-time basis. The practice of burning residuals for energy, however, is long-standing in the forest products industry. It is also of interest, therefore, to examine the net impact from using residuals for energy on an ongoing basis. To do this, one can compare two facilities that are identical, except that one burns residuals for energy year after year while the other facility disposes of the residuals and uses fossil fuels for energy instead. Table ES.6 below, based on the typical scenarios used elsewhere in this study, shows the year when ongoing practices would have to have been initiated in order for the facilities using the residuals for energy production to show net benefits, in terms of cumulative

radiative forcing, in 2014. The table also contains information on the industry's past use of these materials for energy. For the weighted average mix of biomass manufacturing residuals used by the industry, even limiting the analysis to biogenic emissions (ignoring the benefits of fossil fuel displacement), the facility using residuals for energy would be showing net benefits as long as it had started this practice by 2008.

Table ES.6 Ongoing Use of Residuals for Energy Production: Comparing Facilities Using Biomass Residuals for Energy with Similar Facilities Using Fossil Fuels for Energy and Disposing of the Residuals

Residual		Year in the Past When Ongoing Practice Would Have Had To Be Initiated for Cumulative Radiative Forcing from the Two Facilities To Be Equal in 2014 (under typical scenario)	Past Industry Practice in Using the Residuals for Energy
Woody mill residuals	With benefits of the displaced fossil fuels	2012	Based on AF&PA statistics, in 1971, woody mill residual represented 7% of the fuel (16% of the biomass) burned at pulp and paper mills. Wood residuals have been used in saw mills going back to the mid-1800s.
	Without benefits of the displaced fossil fuels	1998	
WWTP residuals	With benefits of the displaced fossil fuels	2014	NCASI statistics on WWTP residuals management go back to 1979, at which point 11% of these residuals was being burned for energy.
	Without benefits of the displaced fossil fuels	2001	
Paper recycling residuals	With benefits of the displaced fossil fuels	2014	NCASI has published information showing the use of recycling residuals for energy in 1975.
	Without benefits of the displaced fossil fuels	1997	
Black liquor	With benefits of the displaced fossil fuels	2014	Based on AF&PA statistics, in 1971, 35% of the fuel (84% of the biomass) burned at pulp and paper mills was black liquor. By 1980, this had increased to 40% of the fuel (79% of the biomass).
	Without benefits of the displaced fossil fuels	2014	
Weighted average of biomass manufacturing residuals	With the benefits of the displaced fossil fuels	2013	N/A
	Without the benefits of the displaced fossil fuels	2008	

†Fiber fraction only.

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ES.5 Conclusions

In this study, the GHG and fossil fuel-related benefits of using woody manufacturing residuals, recycling residuals, and wastewater treatment plant residuals for energy production within the forest products industry were analyzed using life cycle principles and other methods. It was shown that using all types of residuals for energy production produces significant benefits both in terms of reduced fossil fuel consumption and reduced greenhouse gas emissions impacts. This result is valid across a range of system configuration scenarios (boiler type, assumptions about the displaced fossil fuel, the GHG intensity of the electricity grid, and the level of cogeneration at forest products facilities), residual characteristics (e.g., heating value, moisture content), and whether or not the benefits from fossil fuel substitution are considered. These findings hold true whether biogenic CO_2 is included in the analysis or excluded by giving it an emission factor of zero (equivalent to what is sometimes called "carbon neutrality").

The specific GHG results, including biogenic CO_2, for the individual residuals and for the weighted average industry residuals are summarized in Tables ES.2 and ES.3. The benefits occur without affecting the amount of wood harvested or the amount of wood products produced. It typically takes less than 0.6 years for the cumulative radiative forcing associated with emissions from the biomass energy system to be lower than that of the corresponding non-use system, with a weighted average (reflecting industry's typical use of residuals) of less than 0.2 years. Even ignoring the benefits of displacing fossil fuel and limiting the analysis to biogenic emissions, the cumulative radiative forcing impacts associated with emissions from the biomass energy systems are lower than those from the non-use systems in 0 to 7.7 years, depending on the residual, with a weighted average of 2.4 years.

When considered as an ongoing practice (e.g., ongoing production of 1 GJ energy per year), and when displaced fossil fuels are considered, net benefits from using residuals for energy are observed in two years or less. In the case where the benefits of displacing fossil fuels are ignored, the break-even times are longer, but even in this case, considering the weighted average mix of residuals used in the industry, it takes 6 years to realize net benefits from using manufacturing residuals for energy. This means that a facility that began using the average mix of residuals for energy in 2008 would be showing net benefits on an ongoing basis in 2014, even ignoring the benefits of displacing fossil fuels. Black liquor and woody mill residuals comprise 95% of the biomass residuals used in the industry for energy. Kraft black liquor has been commonly burned for energy and chemical recovery since at least the 1950s when the kraft pulping process became widespread. Woody mill residuals have been used for energy at forest products manufacturing facilities since the 1800s.

The GHG emissions reduction benefits of using manufacturing residuals for energy in the forest products industry are large. Given current practice, the use of manufacturing residuals (including black liquor) in the industry for one year avoids an emissions impact of approximately 218 million tonnes CO_2E, equal to more than three times the annual direct emissions associated with the combustion of fossil fuels in the forest products industry.

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National Council for Air and Stream Improvement

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GREENHOUSE GAS AND FOSSIL FUEL REDUCTION BENEFITS OF USING BIOMASS MANUFACTURING RESIDUALS FOR ENERGY PRODUCTION IN FOREST PRODUCTS FACILITIES

1.0   INTRODUCTION AND BACKGROUND

1.1   Background

The use of wood for energy has attracted considerable attention as a greenhouse gas mitigation option (FAO 2008). The United States (US) and Canada are among the largest OECD[3] users of wood for industrial bioenergy, primarily from indirect sources including black liquor and other manufacturing residuals (FAO 2008; Steierer et al. 2007). Wood harvesting and handling, as well as processing activities in log yards, pulp and paper mills, sawmills, and other forest products activities produce a significant amount of residuals, most of which consist of bark, sawdust, shavings, and harvest residuals and other woody debris. These residuals are increasingly being used as a source of renewable energy. Often, however, the residuals that are not beneficially used are either incinerated or placed in a municipal or on-site industrial landfill.

Recent years have seen both a rise in the interest in substituting biomass for fossil fuels and in the skepticism about the greenhouse gas (GHG) benefits of this substitution. While programs that promote the use of biomass as a substitute for fossil fuel have important connections to the issues of energy security and economic sustainability, it is the questions about greenhouse gas mitigation benefits that have been at the center of the debate on whether and how to increase the reliance on the use of biomass for energy.

An important distinction between biomass carbon (also known as biogenic carbon) and the carbon in fossil fuels is that biogenic carbon was only recently removed from the atmosphere. When biomass is burned, decays, or is otherwise oxidized, the resulting CO_2 is returned to the atmosphere. The net transfers of biogenic carbon to the atmosphere can be zero if the uptake of carbon (in CO_2) by growing trees is equivalent to the biogenic carbon released in the combustion and decay of biomass (sometimes referred to as representing "carbon neutrality"). Where the amounts of biogenic CO_2 that return to the atmosphere are less than the amounts removed, the difference represents increases in stocks of stored carbon (net removals from the atmosphere). Where net returns are greater than the amounts removed, the difference represents depleted stocks of stored carbon.

The net transfers of biogenic CO_2 to the atmosphere associated with the production and use of biomass can be used to characterize the GHG emissions associated with a biomass energy system, often called the "carbon footprint" of the system. Understanding the impacts of using biomass for energy, however, requires a different analytical framework than used for a carbon footprint. In studying the impacts of using biomass for energy, one must consider how that energy might be produced if biomass was not used and the fate of the biomass if not used for energy. In this study, the objective was to understand the impacts of using biomass for energy so the life cycle emissions from a system using biomass for energy are compared to the life cycle emissions from alternative systems where the biomass undergoes an alternative fate and fossil fuels are used to produce an equivalent amount of energy.

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[3] Organisation for Economic Co-operation and Development.

1.2   Review of LCA Studies

In recent years, there has been a rapidly increasing number of life cycle assessment (LCA) studies of woody biomass residual energy systems. Table 1.1 provides an overview of the main studies recently published that compared woody biomass residual energy systems with fossil fuel-based energy systems and focused on direct energy production from the residuals, not including studies looking at liquid biofuels. Only studies published in the peer-reviewed literature are presented in this table. The overview does not purport to be exhaustive.

It can be seen from Table 1.1 that these studies have mainly focused on electricity generation and direct heating and that, in cases where the authors looked at the use of woody biomass residuals by forest products facilities (e.g., sawmills), they typically did not consider alternative fates for the residuals. It is also interesting to note that there are very few studies covering other manufacturing residuals from the forest products industry, such as wastewater treatment residuals and paper recycling residuals, and their use for energy production.

In addition, while not traditionally considered in typical LCA studies, the timing of emissions may be an important consideration for certain policy discussion/design contexts. When residuals are burned for energy, the biogenic carbon is immediately released to the atmosphere. In contrast, residuals placed into landfills or left on forest sites degrade slowly, releasing carbon over time. In these cases, the emissions from burning biomass for energy could be higher in the short term than those associated with disposing of the biomass, but this is generally compensated for relatively quickly by the benefits from fossil fuel substitution or benefits from avoiding the disposal emissions of the biomass residuals.

Table 1.1 Published Studies Regarding Life Cycle GHG Mitigation Benefits for Biomass Residuals Energy Systems

Study	Biomass Type	Fossil Fuel Offset	Type of Facility in Which the Biofuel Is Used	Alternative Fate Considered	GHG Mitigation *	Break-Even Time
Boman and Turnbull (1997)	Agricultural residuals, energy crops, forest harvest residuals and sawmill residuals	Coal (power)	US power plants/pulp mill	Not considered	> 90%	Not applicable
Mann and Spath (2001)	Various woody residuals	Coal (power, cofiring)	US power plants	46% landfilling, 54% mulch or conversion to short-lived products	123%[†]	Not available
Robinson et al. (2003)	Forest harvest and agriculture residuals	Coal (power, cofiring)	US power plants	Not considered	≈ 95%	Not applicable
Wihersaari (2005)	Forest harvest residuals	Coal, peat	Finnish power plant	Decomposition in forest	> 75%	Not available
Pehnt (2006)	Forest harvest residuals, woody biomass energy crops, waste wood	German energy mix (power, home heating)	German power plants and homes	Not considered	85-95%	Not applicable
Petersen Raymer (2006)	Fuel wood, sawdust, wood pellets, demolition wood, briquettes, bark	Coal (power, cofiring) and oil (home heating)	Power plants (imports to Norway), Norwegian homes, sawmills, large combustion facilities	Not considered	81-98%	Not applicable
Kirkinen et al. (2008)	Forest harvest residuals (other biomasses not considered here)	Coal, natural gas	Finnish energy sector	Decomposition in forest	Not available	< 20 years‡
Cherubini et al. (2009)	Forest harvest residuals	Various fossil fuels used for heat, power and CHP	Various	Unknown	70-98%	Not applicable

(Continued on next page. See notes at end of table.)

National Council for Air and Stream Improvement

Table 1.1 (Cont'd)

Study	Biomass Type	Fossil Fuel Offset	Type of Facility in Which the Biofuel Is Used	Alternative Fate Considered	GHG Mitigation*	Break-Even Time
Froese et al. (2010)	Forest harvest residuals	Coal (power, cofiring)	US Great Lakes region power plants	Not considered	100%	Not applicable
Jones et al. (2010)	Forest harvest residuals	Natural gas, distillate oil (heat)	Unspecified	Burn at landing	≈ 40-50%‡	Not applicable
Puettmann and Lippke (2012)	Sawmill biomass residuals, pellets, forest harvest residuals	Natural gas (heat, power)	US sawmills	Not considered	57-66%§	Not applicable
Repo et al. (2012)	Forest harvest residuals	Coal, heavy oil, natural gas	Unspecified Finnish facility	Decomposition in forest	29-81%**	< 100 years
Ruhul Kabir and Kumar (2012)	Agricultural residuals, forest harvest residuals	Coal (power, cofiring)	Canadian power plants	Not considered	74-88%*	Not applicable
Zanchi et al. (2012)	Forest harvest residuals	Coal, oil, natural gas	Austrian power plants	Decomposition in forest	76-85%**	0 - 16 years
Gaudreault et al. (2012)	Black liquor	Coal, natural gas (heat and power); US electricity grid	US pulp and paper mills	Biogenic carbon released into CO_2	69-92%	Not applicable

*Percent for full substitution; for cofiring situations the mitigation pertains to the cofire rate (e.g., if 10% fossil fuel is replaced by biomass and emissions decrease by 9%, mitigation of 90% is assigned); includes all GHGs excluding biogenic CO_2. † Mitigation greater than 100% due to avoided end-of-life methane emissions. ‡Estimated. §One of the reasons why Puettmann and Lippke obtained lower mitigation results than other authors for manufacturing residuals is that they allocated a fraction of the load from manufacturing to the residuals. **Values at 100 years.

2.0   STUDY OBJECTIVES

The main objective of this study was to evaluate the life cycle (cradle-to-final energy analysis) greenhouse gas impact (GHGI) and fossil fuel reduction benefits of using various forms of forest biomass residuals (manufacturing-related) for energy production in forest products manufacturing facilities in contrast to no beneficial use of these residuals coupled with production of the same quantity and form of energy using fossil fuels. The total 100-year and yearly impacts were investigated.

The study also included two secondary objectives: 1) to analyze the greenhouse gas impact from the emissions of biogenic GHGs released from the units in which the residuals are managed (i.e., combustion units or landfills, gate-to-gate analysis); and 2) to analyze the annual and cumulative greenhouse gas impact associated with the net emissions attributable to the use of the residuals for

energy as an ongoing, long-standing, practice (both in terms of cradle-to-final energy and gate-to-gate boundaries).

The biomass residuals studied in this project were

- woody mill residuals (e.g., bark, sawdust, and other similar manufacturing woody residuals from sawmills, panel plants, and pulp and paper mills);
- wastewater treatment plant (WWTP) residuals; and
- paper recycling residuals (e.g., old corrugated container (OCC) rejects)[4].

For each type of residuals, the study compared a base case of no beneficial use of residuals (including their alternative fates) with 100% use for energy generation. Note that whether or not these residuals are used for energy production, the same number of trees would be harvested and the same quantity of resources would still be required to produce the related forest products. In addition to heat production, the study also included combined heat and power (CHP) as a second option for using the residuals. Other options for processing or using the wood residuals (e.g., torrefaction, gasification, hydrolysis and fermentation, other beneficial uses) were not analyzed.

3.0   INTENDED APPLICATION AND TARGETED AUDIENCE

The intended application is to inform the discussion and development of policies that require an understanding of the impacts of using biomass-based manufacturing residuals for energy at forest products manufacturing facilities. The targeted audience of this report is individuals interested in understanding these impacts.

4.0   METHODS

4.1   Cradle-to-Final Energy Analysis

4.1.1   Overview Methodology Employed

Life Cycle Assessment (LCA) is the *"compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle,"* the life cycle being *"consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal"* (ISO 2006a, p. 2).

LCA principles and methodology are framed by a set of standards (ISO 2006a, b) and technical reports and specifications (ISO 2002, 2012a, b) from the International Organization for Standardization (ISO). ISO describes LCA methodology in four phases:

1) **Goal and scope definition,** in which the aim of the study, the product system under study, its function and functional unit, the intended audience, and the methodological details on how the study will be performed are defined;

2) **Life cycle inventory analysis (LCI),** which is the *"phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle"*(ISO 2006a, p. 2);

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[4] Paper recycling residuals are materials removed during processing to eliminate contaminants and yield reusable fiber.

3) **Life cycle impact assessment (LCIA),** which is the "phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product" (ISO 2006a, p. 2); and

4) **Life cycle interpretation,** which is the *"phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations"* (ISO 2006a, p. 2).

This study

- used widely accepted LCA concepts, such as those described in LCA ISO standards 14040 and 14044 (International Organization for Standardization (ISO) 2006a, b);
- was built on the approaches by others [e.g., US Environmental Protection Agency (EPA), Consortium for Research on Renewable Materials (CORRIM)];
- was based on known and established competitive materials and alternative fates for biomass residuals; and
- did not consider any "export" of the residuals outside the forest products industry (e.g., to utilities).

More specifically, the methodology used in this study followed life cycle principles, by calculating emissions from "cradle to final energy" including fuel conversion efficiency. However, a simplified (streamlined) LCA methodology was applied. Streamlining generally can be accomplished by limiting the scope of the study or simplifying the modeling procedures, thereby limiting the amount of data or information needed for the assessment (Todd and Curran 1999). Many different streamlining approaches can be applied. In this study, two main approaches were taken: limiting the impact assessment to two indicators (global warming, fossil fuel consumption) and for the most part using generic information. Because of this, this study does not fully comply with ISO 14044 requirements for comparative assertions disclosed publicly. However, the study aligns as much as possible with this standard.

4.1.2   Functions and Functional Units

In this study, the primary functional unit was **the production of 1 GJ of energy**. The product systems being compared also fulfilled an additional implicit function which is the management of the quantity of residuals required to produce 1 GJ of energy. This is further discussed in Section 4.1.4.

4.1.3   Scenario and Sensitivity Analyses

The overall analysis approach employed in this study is depicted in Figure 4.1. First, for each system component of the study (size reduction, biomass energy production, alternative fates of the residuals and fossil fuel displaced), possible scenarios were defined. These scenarios were intended to represent a broad range of conditions in the US forest products industry.

Then, a typical scenario was established for each residual type as the best estimate for representing average conditions in the US in terms of the different system components mentioned above. The typical scenario was analyzed to determine typical benefits obtained by using a given residual type, the contribution of each different system component to the overall results, the sensitivity of various parameters (e.g., higher heating value, water content, etc.) to the results, and the effect of time on the results. Where possible, each parameter was analyzed using a base case, low, and high value.

Perturbation analyses were also performed. The general idea behind perturbation analyses is that perturbations of the input parameters propagate as smaller or larger deviations to the resulting output (Heijungs and Kleijn 2001). The objectives of perturbation analyses are to provide 1) a list of those input parameters for which a small imprecision already leads to important changes in the results, and 2) interesting suggestions for improving the environmental performance of the system. For each parameter tested in sensitivity analysis, a perturbation analysis was also performed and a sensitivity ratio was calculated as outlined below.

Sensitivity ratio = Percent change in output variable/Percent change in input variable

The input variable is the parameter tested in sensitivity analysis while the output variable is a given environmental indicator (see more detail in Section 4.1.6). For instance, a sensitivity ratio of +1.0 means that the score of the environmental indicator increases by 1% when the parameter value is increased by 1%. The more negative an environmental indicator score, the better the performance of the biomass energy system compared to the non-use system. The more positive or the more negative a sensitivity ratio is, the more sensitive a parameter is.

Figure 4.1 Study Overall Approach for the Life Cycle Based Analyses

National Council for Air and Stream Improvement

4.1.4 Product Systems Studied, System Boundaries, and Allocation

For each type of residual, the study compared a base case of no beneficial use of residuals (while accounting for their alternative fate) with 100% use for energy generation. The different product systems studied and compared in this study are discussed next. The general approach was to include within the system boundary only the processes that were different between the biomass and non-use systems.

4.1.4.1 Woody Mill Residuals

Major sources of manufacturing residuals include sawmills, panel plants, and pulp and paper mills. These residuals consist primarily of bark and fine residuals (e.g., sawdust, planer shavings, sanderdust). In this study, all woody mill residuals were considered as a whole, in a single analysis. Sensitivity analyses were performed to encompass the variability in residual types (see Section 5.1).

Figure 4.2 illustrates the two product systems that were compared in the case of woody mill residuals.

1) **Biomass Energy System:** Production of 1 GJ of energy (heat or combined heat and power) using manufacturing residuals.
2) **Non-Use System:** Production of 1 GJ of energy (in the same form as in #1) using fossil fuels and alternative fate of the residuals.

Figure 4.2 also shows that the accounting started with the manufacturing-related biomass residuals and ended at the point at which the energy has been generated. All of these materials would be generated whether or not they would be used for energy generation, and thus there should be no effects on upstream processes attributable to the use of the materials for energy. Therefore, upstream emissions from the production of these materials were assumed to be the same for both systems and they were not included in the analysis.

In some cases, size reduction of manufacturing residuals is required. As depicted in Figure 4.2, three scenarios were considered regarding size reduction (SR0: no size reduction, SR1: size reduction in mobile chipper, and SR2: size reduction in stationary chipper). These processes, as well as any related upstream emissions, were included in the system boundary of the biomass energy system only as they were considered to be unnecessary in the non-use system. The system boundary of the biomass energy system also included the processes required to produce the energy at forest products facilities. Five system configuration scenarios were considered: heat production only in a stoker boiler (SB), heat production only in a fluidized bed boiler (FB), and three levels of combined heat and power (CHP1, CHP2, and CHP3) in which the heat is produced in a stoker boiler.

The non-use system included the upstream emissions for producing the fossil fuel and the energy production processes at forest products facilities or utilities. The energy produced was set to be in the same form as in the biomass energy system. Figure 4.2 shows the different system configurations that were analyzed regarding energy production in the non-use system. It was assumed that heat could be produced in forest products facilities using either coal (A) or natural gas (B). Electricity production at utilities (see Section 5.1) was assumed to be represented by the US average grid (C), coal (D), or natural gas combined cycle (E). When using woody mill residuals to produce 1 GJ of energy, an implicit secondary function is accomplished: the management of the quantity of residuals necessary to produce 1 GJ of energy (Q_R). For the two compared systems to be equivalent, it was necessary to expand the boundary of the non-use system to account for an alternative fate for these residuals. Figure 4.2 shows the two scenarios that were considered for the alternative fate of residuals in the non-use systems: 1) placed in landfills (MR1), and 2) incinerated without recovering the energy

(MR2). The typical scenario definition and rationale, and more details on the various unit processes involved in both systems, are provided in Section 5.1.

Figure 4.2 Compared Product Systems for Woody Mill Residuals

4.1.4.2   WWTP Residuals

Another manufacturing residual that was included in the study is wastewater treatment plant (WWTP) residuals. Figure 4.3 illustrates the two systems that were compared for WWTP residuals:

1) **Biomass Energy System:** Production of 1 GJ of energy (heat, power or combined heat and power) using the WWTP residuals; and

2) **Non-use System:** Production of 1 GJ of energy (in the same form as in #1) using fossil fuels and alternative fate of the WWTP residuals.

Figure 4.3 also shows that the accounting started with the WWTP residuals and ended at the point at which the energy has been generated. WWTP residuals would be generated whether or not they are used for energy generation, and thus there should be no effects on upstream processes attributable to the use of these materials for producing energy. Therefore, upstream emissions from the production of these materials were assumed to be the same for both systems and they were not included in the analysis. It was also assumed that mechanical dewatering would be required whether the residuals would be used for energy generation or disposed of, and hence was not included in the study.

The system boundary of the biomass energy system included the processes required to produce the energy at forest products facilities. Four system configuration scenarios were considered: heat production only in a stoker boiler (SB), and three levels of combined heat and power (CHP1, CHP2, and CHP3) in which the heat is produced in a stoker boiler.

The non-use system included the upstream emissions for producing the fossil fuel and the energy production processes at forest products facilities or utilities. Figure 4.3 shows the different system configurations that were analyzed. It was assumed that heat could be produced in forest products facilities using either coal (A) or natural gas (B). Electricity production at utilities (see Section 5.1) was assumed to be represented by the US average grid (C), coal (D), or natural gas combined cycle (E). When using WWTP residuals to produce 1 GJ of energy, an implicit secondary function is accomplished: the management of the quantity of residuals necessary to produce 1 GJ of energy (Q_R). For the two compared systems to be equivalent, it was necessary to expand the boundary of the non-use system to account for an alternative fate for these residuals. Figure 4.3 shows the two scenarios that were considered for the alternative fate of residuals in the non-use systems: 1) placed in landfills (MR1), and 2) incinerated without recovering the energy (MR2). The non-use system included the upstream emissions for producing the fossil fuel and the energy production processes at forest products facilities or utilities. The typical scenario definition and rationale, and more details on the various unit processes involved in both systems, are provided in Section 5.1.

Figure 4.3 Compared Product Systems for WWTP Residuals

4.1.4.3   Paper Recycling Residuals

The last manufacturing residual that was included in the study is paper recycling residuals, and more specifically old corrugated container (OCC) rejects. Figure 4.4 illustrates the two systems that were compared for paper recycling residuals.

1) **Biomass Energy System:** Production of 1 GJ of energy (heat, power or combined heat and power) using the paper recycling residuals.
2) **Non-Use System:** Production of 1 GJ of energy (in the same form as in #1) using fossil fuels and alternative fate of the paper recycling residuals.

Figure 4.4 also shows that the accounting started with the paper recycling residuals and ended at the point at which the energy has been generated. Paper recycling residuals would be generated whether or not they would be used for energy generation, and thus there should be no effects on upstream processes attributable to the use of the materials for energy. Therefore, upstream emissions from the production of these materials were assumed to be the same for both systems and they were not included in the analysis.

The system boundary of the biomass energy system included the processes required to produce the energy at forest products facilities. Four system configuration scenarios were considered: heat production only in a stoker boiler (SB), and three levels of combined heat and power (CHP1, CHP2, and CHP3) in which the heat is produced in a stoker boiler.

The non-use system included the upstream emissions for producing the fossil fuel and the energy production processes at forest products facilities or utilities. Figure 4.4 shows the different system configurations that were analyzed. It was assumed that heat could be produced in forest products facilities using either coal (A) or natural gas (B). Electricity production at utilities (see Section 5.1) was assumed to be represented by the US average grid (C), coal (D), or natural gas combined cycle (E). When using paper recycling residuals to produce 1 GJ of energy, an implicit secondary function is accomplished: the management of the quantity of residuals necessary to produce 1 GJ of energy (Q_R). For the two compared systems to be equivalent, it was necessary to expand the boundary of the non-use system to account for an alternative fate for these residuals. Figure 4.4 shows the two scenarios that were considered for the alternative fate of residuals in the non-use systems: 1) placed in landfills (MR1), and 2) incinerated without recovering the energy (MR2). The non-use system included the upstream emissions for producing the fossil fuel and the energy production processes at forest products facilities or utilities. The typical scenario definition and rationale, and more details on the various unit processes involved in both systems, are provided in Section 5.1.
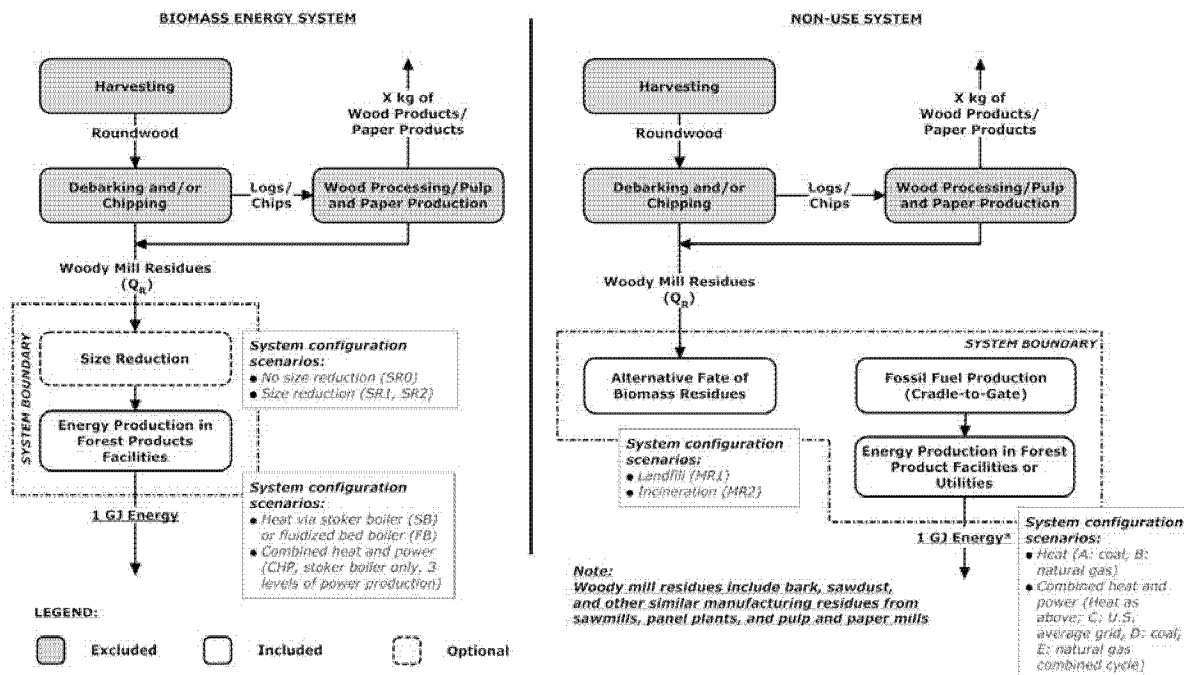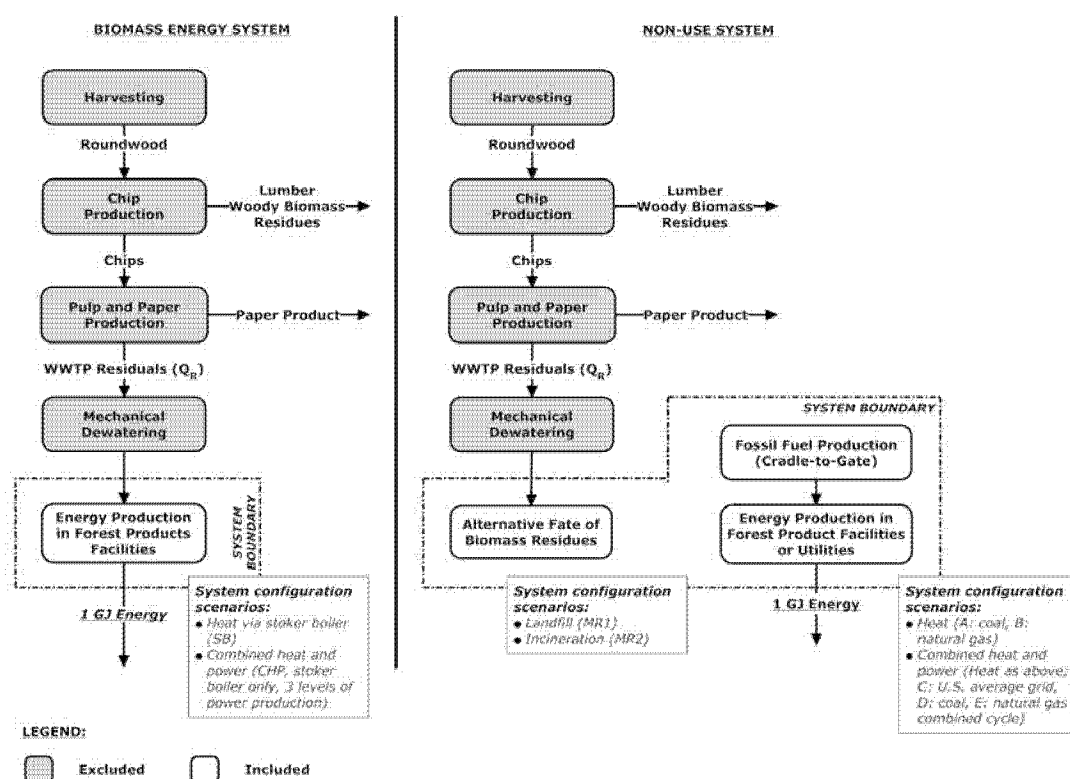

Figure 4.4 Compared Product Systems for Paper Recycling Residuals

4.1.5   Exclusions and Cut-Off Criteria

For each of the groups described above, the following components of each product system were not included in this study: manufacture of capital equipment, human activities, and unit processes common to the systems compared.

All required data were available. No cut-offs were applied.

4.1.6   Environmental Indicators Analyzed

Two main environmental aspects were studied in this study: greenhouse gases (GHGs) and fossil fuel consumption.

Note that in LCA studies, environmental indicator results are relative expressions and do not predict impacts on category endpoints, nor the exceeding of thresholds, safety margins, or risks.

4.1.6.1   Greenhouse Gas Impact (GHGI)

In this report, the term "greenhouse gas impact" is used to describe the cumulative radiative forcing over a period of time that is attributable to emissions of greenhouse gases. Various approaches can be used to calculate the greenhouse gas impact. The most common approach is to use the 100-year global warming potentials (GWPs) published by the Intergovernmental Panel on Climate Change (IPCC 2006c). The 100-year global warming potentials calculated by IPCC represent the cumulative radiative forcing over 100 years attributable to a pulse release of a GHG relative to the forcing attributable to a pulse release of the same mass of CO_2.Using this approach, the 100-year greenhouse impact is assumed to occur the same year as the pulse emission. The results are typically expressed as kilograms of CO_2 equivalents (kg CO_2E). GWPs are useful in developing GHG inventories in a way that allows the impacts associated with different types of emissions to be compared over 100 years, or some other period. IPCC has published GWPs for periods of 20, 100, and 500 years. In this study, the timing of impacts was of particular interest, which required a dynamic calculation of cumulative radiative forcing as a function of time. To accomplish this, a dynamic carbon footprinting approach developed by Levasseur (2013) and Levasseur et al. (2010) was used. This approach produces time-dependent global warming results based on the cumulative radiative forcing concept. The same scientific models are used in the dynamic carbon footprinting approach as used by IPCC to develop global warming potentials but the equations are integrated continuously over time with the exception of one element (see below). Although the results are typically expressed in units of radiative forcing (Wm^{-2}), they can also be presented in terms of kg CO_2E, especially if the objective is to compare the results to those obtained using GWPs. Approaches similar to the approach proposed by Levasseur et al. were used elsewhere (e.g., Alvarez et al. 2012).

A difference between the dynamic approach proposed by Levasseur et al. (2010) and IPCC's scientific models was mentioned above. The approach proposed by Levasseur et al. includes the radiative forcing associated with CO_2 formed when methane decomposes in the atmosphere while IPCC's GWPs for methane do not (IPCC 2007, Chapter 2, paragraph 2.10.3). Because this study is attempting to identify the difference in total impacts between systems over time, it is appropriate to include the radiative forcing associated with CO_2 produced from the decomposition of methane in the atmosphere. Simulations performed by NCASI comparing the method of Levasseur et al. to IPCC global warming potentials indicate that the effect of this difference on results is relatively small over periods of interest in this study (i.e., 100 years and less). Table 4.1 shows the results of applying the dynamic approach compared to the most recent 100-year global warming potentials from IPCC (IPCC 2006c). The results using both approaches are also shown in several places in this report.

Table 4.1 Comparison of IPCC GWPs to Results Obtained Using the Dynamic Carbon Footprint
Calculator by Levasseur et al.

GHG	20-Year		100-year		500-year	
	IPCC GWPs	Dynamic Calculator	IPCC GWPs	Dynamic Calculator	IPCC GWPs	Dynamic Calculator
Methane	72	72.9	25	27.5	7.6	10.3
Nitrous Oxide	289	289	298	298	153	153

In this study, the results for the GHGI indicator have been computed in three different ways, both for the IPCC 100-year GWPs and using the dynamic calculator.

First, the absolute difference in impact attributable to releases of GHGs over 100 years, including biogenic CO_2 emissions and removals[5] was used to calculate the results of the greenhouse gas impact indicator ("Differential GHGI") as follows:

Differential GHGI (kg CO_2E/GJ) = Total greenhouse gas impact caused by GHG releases, including biogenic CO_2 emissions and removals, for energy production using residuals – Total greenhouse gas impact of GHG releases, including biogenic CO_2 emissions and removals, for energy production using fossil fuels, including alternative fate of residuals

Or in a shorter form:

Differential GHGI (kg CO_2E/GJ) =
[Total GHGI[6]]$_{Biomass system}$ - [Total GHGI]$_{Non-use system}$

Second, the greenhouse gases impact was computed using the percent difference in radiative forcing or GHGI impact calculated using IPCC GWPs attributable to GHGs released over 100 years, not including biogenic CO_2 ($BioCO_2$), of the biomass energy system compared to the non-use system ("Relative Non-$BioCO_2$ GHGI") as follows:

Relative Non-$BioCO_2$ GHGI (%) = (greenhouse gas impact caused by GHG releases, not including biogenic CO_2, for energy production using residuals – greenhouse gas impact caused by GHG releases, not including biogenic CO_2, for energy production using fossil fuels, including alternative fate of residuals)/(greenhouse gas impact caused by GHG releases, not including biogenic CO_2, for energy production using fossil fuels, including alternative fate of residuals)

Or in a shorter form:

Relative Non-$BioCO_2$ GHGI (%) =
[(GHGI, excl. $BioCO_2$)$_{Biomass energy system}$ - (GHGI, excl. $BioCO_2$)$_{Non-use system}$]/ (GHGI, excl. $BioCO_2$)$_{Non-use system}$

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[5] As described in Figures 4.2 to 4.4, the system boundary for the product systems did not include harvesting and forest-related activities because they are the same in the biomass and non-use systems. This means that the associated forest-related CO_2 removals, i.e., the sequestration or absorption of CO_2 from the atmosphere by the trees, were not included in this study.

[6] In this report, "Total GHG releases" is used as a short form for the sum of non-biogenic CO_2 GHGs and biogenic CO_2 GHGs.

Third, while not traditionally considered in typical LCA studies, the timing of emissions and of greenhouse gas impact may be an important consideration for certain policy discussion/design contexts. For instance, in the context of this study, timing may be important in cases where the alternative to using residuals is allowing them to decay in waste disposal sites. Therefore, this study examined the life cycle implications of using biomass residuals for energy as a function of time. For each residual, the study computed the number of years it would take for the cumulative greenhouse gas impact from the two systems to be equal (break-even time). After this time, the cumulative greenhouse gas impacts from the biomass systems remain lower than that from the non-use system for remainder of the 100-year period of study. While the Differential GHGI results are presented in terms of kg CO_2E to facilitate comparison with using the 100-year IPCC GWPs, the yearly differential impact is presented in terms of radiative forcing because the graphical results are much easier to interpret when presented in terms of radiative forcing units (Wm^{-2}).

Notes:

- The materials being examined are biomass residuals. Their use was assumed to have no effect on carbon in growing biomass or gross removals of carbon from the atmosphere by the forest.
- Carbon in products-in-use was not modeled in this study because the fate of carbon in products is not affected by the fate of the residuals.

4.1.6.2   Fossil Fuel Consumption

Fossil fuel used in the life cycle of each of the product systems studied was computed. The relative fossil fuel consumption ("Relative FF CON") was calculated as follows:

Relative FF CON (%) = (fossil fuel consumption score for energy production using residuals – fossil fuel consumption score for energy production using fossil fuels, including alternative fate of residuals)/(fossil fuel consumption score for energy production using fossil fuels, including alternative fate of residuals)

Fossil fuel consumption indicators are not based on an impact assessment model but rather on a quantification of the energy inputs to the studied product system. The cumulative energy demand method (Hischier and Weidema 2009) was used to quantify fossil fuel consumption because it is the most consistent with the life cycle inventory database used in this study. This method uses higher heating values in an attempt to characterize the total amount of energy consumed rather than only the energy directly used within the system being studied. The cumulative energy demand method tracks energy from the point of extraction.

Note: In this report, when a percent reduction is discussed, it is always compared to the non-use system as defined in this study, unless otherwise mentioned.

4.1.7   Temporal Boundary

The temporal boundary describes within what time horizon the results of the LCA are analyzed. The temporal boundary applies to inventory data and to the impact assessment. In this study, a temporal boundary of 100 years was selected because anything beyond that was judged to be too uncertain in relation to the goal of the study. This means that emissions were considered within 100 years after the residuals are used for energy or discarded. The greenhouse gas impact was also analyzed within this same 100-year time frame. When using IPCC GWPs, the greenhouse gas impact of an emission over 100 years is assumed to occur in the same year as the emissions. As a result, when using 100-year GWPs to study systems where emissions occur over time, some of the impacts associated with emissions occurring after year 1 actually occur after the 100-year period is ended.

4.2   Methodology for Additional Analyses

In addition to the life cycle analyses described above, the study also included two secondary analyses: a gate-to-gate analysis of the fate of biomass carbon, and one of the GHG emissions from the ongoing use of residuals for energy production.

4.2.1   Gate-to-Gate Analysis of Biogenic GHGs

The gate-to-gate analysis consisted of a more constrained analysis of the emissions of biogenic GHGs (mainly CO_2, CH_4, and N_2O) in isolation from any fossil fuel substitution benefits. In this analysis, the two compared systems (the biomass energy system and the non-use system) have been compared in terms of the emissions coming directly out of the units receiving the residuals (combustion units or landfills). In the case of paper recycling residuals, only their fiber fraction was considered as the focus here was on the fate of the biomass carbon. In this analysis, the system boundary for the various product systems was limited to the units receiving the residuals (i.e., "Energy Production in Forest Products Facilities" and "Alternative Fate of Biomass Residuals" in Figure 4.2 to Figure 4.4). The results were computed for two indicators described previously: differential GHGI and break-even times. A temporal boundary of 100-years was also used for that analysis.

4.2.2   GHG Emissions from Ongoing Use of Residuals for Energy Production

The analyses presented above focused on the one-time production of 1 GJ of energy (the functional unit) and looked forward in time to estimate the number of years it will take before the emissions attributable to the one-time use of biomass for energy are less than the emissions from a comparable system that disposes of the residuals. The practice of burning residuals for energy, however, is long-standing in the forest products industry. Therefore, it was also of interest to examine the net greenhouse gas impact over time attributable to the use of manufacturing residuals for energy on an ongoing basis. To look at the greenhouse gas impact from the ongoing use of biomass for energy production, a different functional unit is required. The functional unit used to assess emissions from ongoing practice is ***"The yearly production of 1 GJ of energy using biomass residuals as an ongoing practice."***

The definition of the temporal boundary is slightly different when analyzing the emissions attributable to ongoing practice. In fact, there are two points in time to consider. The first is the time required for the annual greenhouse gas impact from a facility using residuals for energy on an ongoing basis to equal the annual greenhouse gas impact of a facility disposing of those residuals. The second is the time it takes for the cumulative greenhouse gas impact from a facility using residuals for energy on an ongoing basis to equal the cumulative greenhouse gas impact of a facility disposing of those residuals. It takes longer for the cumulative greenhouse gas impact from the two facilities to become equal than it does for the annual greenhouse gas impact to become equal.

Data from AF&PA and NCASI were used to document the forest product industry's practices related to the use of biomass residuals for energy production.

4.3   Summary of Data Sources

North American data were used where possible and data gaps were filled using European data. The main data sources are summarized in Table 4.2.

Table 4.2 Data Sources

Process	Data Source
Direct combustion of wood residuals	NCASI, USEPA emission factors, literature
Direct combustion of WWTP residuals	Literature, NCASI
Combined heat and power from direct combustion	NCASI data
Landfilling	USEPA, NCASI
Production of energy using fossil fuels	US-EI Database* (EarthShift 2009) modified to US 2010 power grid
Transportation distances	US Census 2002 (US Department of Transportation and US Department of Commerce 2004)
Transportation processes	US-EI Database (EarthShift 2009)

* The US-EI database (EarthShift 2009) bridges the current gap in the US LCI database (National Renewable Energy Laboratory 2008) and applies US electrical conditions to the ecoinvent database (Swiss Center for Life Cycle Inventories 2010). The database includes modified processes for the 423 processes contained in the US LCI database (version 1.6) and for the 3,974 unit processes contained in the ecoinvent database (version 2.2). Specifically, for the US LCI Database, most dummy processes (processes for which no life cycle information was available) were replaced with ecoinvent proxies using US electricity. Some of the dummy processes were not replaced if they were not available in the ecoinvent data set. For the ecoinvent data set, all processes using electricity from Switzerland or one of the European regions (RER, UCTE, CENTREL or NORDEL) were indirectly adapted to instead use US electricity. This was done by rerouting data for electricity production/distribution to data for US electricity production/distribution. NCASI also updated the data for electricity production to the most recent available data. The main data sets from the US-EI database that were used in this study are documented in this report. A data set with the "WITH US ELECTRICITY" mentioned in its title was originally developed by ecoinvent, while a data set with the "NREL" mentioned in its title was originally developed by the US LCI database.

4.4   Data Quality Goals

The ISO 14044 Standard (ISO 2006b) characterizes various aspects related to data quality and data quality analysis. It lists three critical data quality requirements: time-related coverage, geographical coverage, and technology coverage. The geographic coverage for this study is related to energy produced in US forest products facilities and utilities. When feasible, the most current available data were collected, which were most frequently for 2010. For data from secondary sources (literature, databases), the most current publicly available data for North America were used. A data quality goal of this study was to depict the GHG benefits of using biomass residuals within the forest products industry in a way that is representative of current average technology across the entire industry. Data were most frequently available from the members of the American Forest and Paper Association (AF&PA) and/or NCASI. Data obtained from these members were considered representative of the broader industry. The precision of the data is discussed where appropriate.

4.5   Energy Considerations

Energy requirement calculations were made using higher heating values (HHVs). HHVs account for the total heat content of the fuel when it is burned, some of which provides useful energy to the system in which the fuel is burned and some of which is used to evaporate the water in the combustion products. The latter is generally not available for use. For life cycle purposes, HHV is a more complete method of energy accounting compared to using the lower heating value (LHV), as LHV does not account for the energy content of the fuel that was used to evaporate the water. For this reason, HHVs were used in this study.

4.6   Software Package

This modeling for this study was performed using SimaPro™ version 7.3.3 and DynCO$_2$ (Levasseur 2013).

4.7   Critical Review and Public Use of the Results

Section 5.2 of ISO 14044 (ISO 2006b, p. 28) specifies that *"when results of the LCA are to be communicated to any third party (i.e., interested party other than the commissioner or the practitioner of the study), regardless of the form of communication, a third-party report shall be prepared"*. This Technical Bulletin is intended to serve as a third-party report. The Standard also specifies that *"in order to decrease the likelihood of misunderstandings or negative effects on external interested parties, a panel of interested parties shall conduct critical reviews on LCA studies where the results are intended to be used to support a comparative assertion intended to be disclosed to the public"* (ISO 2006b, p. 31). This study constitutes a comparative assertion of biomass and non-use systems. However, no formal peer review was performed, meaning that the study is not fully compliant with the ISO 14044 Standard.

5.0   DETAILED DATA SOURCES AND STUDY ASSUMPTIONS

This section describes the life cycle inventory step of the LCA, in which the typical scenarios studied are described, as are the unit processes modeled, the related system configuration scenarios, and sensitivity analyses.

5.1   Detailed Description of Unit Processes, System Configurations and Sensitivity Analyses

Table 5.1 presents an overview of the individual components that were combined into the various system configurations scenarios that were studied in this project. All possible combinations were studied, with a few exceptions that are discussed later in this section of the report, as appropriate. From these possible configurations, a typical scenario was also constructed for each of the biomass residuals studied. These are presented in Section 5.1.2.5. The next paragraphs describe in detail each of the unit processes that were involved in the various system configurations and typical scenarios.

Table 5.1 Summary of Components Used to Derive Possible System Configurations

Pre-Processing		Energy Produced at Forest Products Facilities Using Biomass Residuals		Energy Produced at Forest Products Facilities Using Fossil Fuels		Alternative Fate of Residuals	
SR0	No size reduction	SB	Heat from stoker boiler	A	Heat from natural gas	MR1	Landfill
		FB	Heat from fluidized bed	B	Heat from coal		
SR1	Size reduction	CHP1	Combined heat and power: low power to steam ratio*	C	Power from average US grid	MR2	Incineration
		CHP2	Combined heat and power: medium power to steam ratio*	D	Power from coal		
		CHP3	Combined heat and power: high power to steam ratio*	E	Power from natural gas combined cycle		

*All CHP scenarios were based on the use of a stoker boiler to produce the heat from biomass residuals. CHP configurations vary from facility to facility. In some cases, the turbines used to produce the power receive steam from all boilers of the facility (biomass and fossil fuel boilers). In other cases, they receive steam only from specific boilers (biomass or fossil fuel). Analyzing a case where the same amount of CHP would be achieved using biomass or fossil fuel boilers would have led to results that are very similar to those obtained for cases where it was assumed there was only heat produced because the only difference would have been due to energy losses in the CHP system. Therefore, in this project, a more useful CHP scenario for comparison is one where there would be CHP production only in the biomass energy system; if biomass residuals would not be used for energy production at wood products facilities, then the facility would have burned fossil fuel without CHP and would have to purchase the power from local utilities.

5.1.1 Size Reduction of Biomass Residuals

In some cases, additional size reduction is necessary before using biomass residuals for energy production. In this study, it was assumed that size reduction would sometimes be required for woody mill biomass residuals fuel and other similar manufacturing biomass residuals and never required for WWTP and paper recycling residuals.

Size reduction is typically accomplished by means of chippers, hogs, and shredders. Chippers can slice logs and mill residuals and produce chips with two surfaces and clean edges of pre-specified dimensions. Hogs (e.g., hammermills) and shredders reduce wood particles through impact force, and thus produce coarse and multi-surface particles. Hybrid size reduction equipment, such as rotary knife hogs or pan-and-disc grinders, combine the durability of hogging equipment with the sharp cutting action of chippers to produce wood chunks with cleaner edges than those produced by shredders or hogs.

A few data sets, summarized in Table 5.2, were found in the literature concerning size reduction of wood. These served as the basis for this study. More specifically, size reduction-related emissions were modeled using the US-EI database, modified with the use of diesel and electricity as presented in this table. The following US-EI data sets were used:

- **Mobile chipper:** "Wood chopping, mobile chopper, in forest/RER WITH US ELECTRICITY"; and
- **Stationary chipper:** "Industrial residual wood chopping, stationary electric chopper, at plant/RER WITH US ELECTRICITY."

Table 5.2 Various Available Data Sets for Size Reduction and Assumptions Made in This Study

Source	Operation		Diesel (L/BDmT)	Lubricants (L/BDmT)	Electricity (kWh)
Johnson et al. (2012)	Grinding of logging residuals		2.90 - 3.90	0.05 - 0.07	0
Johnson et al. (2012)	Chipping of thinnings		1.08 - 1.62	0.02 - 0.03	0
Werner et al. (2007)	Chopping of wood in mobile choppers		4.14*	0.06†	0
Werner et al. (2007)	Chopping in stationary chopper		0	0.002†	20
Jones et al. (2010)	Grinding of thinnings		1.7	N/Av.‡	0
System Configuration Scenarios and Sensitivity Analyses Considered in This Study					
SR0	No additional size reduction		0	0	0
SR1	Additional size reduction in mobile chipper	BC	2.49	0.05	0
SR1	Additional size reduction in mobile chipper	Low	1.08	0.02	0
SR1	Additional size reduction in mobile chipper	High	3.90	0.07	0
SR2	Additional size reduction in stationary chipper	BC	0	0.002	20

*Using a density of 847.31 kg/m^3 (American Petroleum Institute 2009). † Assuming a density of 900 kg/m^3.‡Not available.

5.1.2   Energy Production Processes

5.1.2.1   Combustion of Woody Mill Residuals

Combustion of woody mill residuals is one of the unit processes that needed to be modeled to analyze the effects of producing energy using biomass residuals. Two types of boilers were modeled. First, a stoker boiler was assumed as it is the most commonly used firing method for burning woody biomass in the US forest products industry (NCASI 2011a). Stoker boiler efficiencies vary as a function of water content of the fuel. This is depicted in Figure 5.1. Sensitivity analyses were performed on water content and higher heating values. Second, to analyze the effect of the technology choice, a fluidized bed was also modeled using a single average residual water content and a single average higher heating value. Because smaller particles are required for a fluidized bed boiler, the analyses always incorporated size reduction. Table 5.3 summarizes the parameters that were varied for the modeling of manufacturing biomass residual combustion.

In addition, woody mill residuals are either used for energy production in the facility where they are generated or transported to another wood products facility. No transportation has been considered for the base case and transportation by truck over 130 km (US Department of Transportation and US Department of Commerce 2004) was modeled as a sensitivity analysis. The US-EI data set for single unit truck ("Transport, single unit truck, diesel powered NREL/US"), originally a US LCI Database data set, was used in this study.

Figure 5.1 Stoker Boiler Efficiency as a Function of Fuel Water Content (WC$_R$)
[Based on Kostiuk and Pfaff (1997)]

Table 5.3 Base Case and Sensitivity Analyses for Manufacturing Biomass Residual Combustion

Technology Scenario		Parameter Analyzed	Value Analyzed		Comments
SB	Stoker boiler	Water content (W$_R$)	BC	50% (Eff = 66%)	The range of water content for wood residuals was based on a literature review by NCASI (2011a) and assumed to be representative of the full range of wood residuals (e.g., chips, sawdust, etc.). Efficiencies were based on Forintek (Kostiuk and Pfaff 1997). According to NCASI's literature review, water content of residuals can be as high as 75%, but this is not very realistic.
			Low	10% (Eff = 79%)	
			High	60% (Eff = 60%)	
		Higher heating value (HHV)	BC	20 GJ/BDmT	The range of heating values is based on a literature review by NCASI (2011a) and is assumed to be representative of the full range of wood species (hardwood and softwood). USEPA (2009, Tables C-1 and C-2) proposed heating value for wood is 20.3 GJ/BDmT (see below for more details).
			Low	13 GJ/BDmT	
			High	26 GJ/BDmT	
FB	Fluidized bed	Water content	50% (Eff = 80%)		Efficiency for the fluidized bed was from a NCASI literature review (2011a).
		Higher heating value	20 GJ/BDmT		

The amount of residuals (Q_R) in dry tonnes required to produce a given amount of usable energy was calculated as follows:

$$Q_R = \frac{E_{DC}}{HHV \times Eff}$$

Where:

E_{DC}: Usable energy from direct combustion (GJ);
HHV: Higher heating value (GJ HHV/BDmT); and
Eff: Boiler efficiency (%).

GHG emissions due to biomass residual combustion were modeled using emission factors from USEPA (2009, Tables C-1 and C-2), converted to physical units[7]:

- 1,807 kg BioCO$_2$[8]/BDmT;
- 0.617 kg CH$_4$/BDmT; and
- 0.0809 kg N$_2$O/BDmT.

Ashes were assumed to be disposed of in facility landfills. Landfilling of wood ashes was modeled using data from the US-EI database ("Disposal, wood ash mixture, pure, 0% water, to sanitary landfill/CH WITH US ELECTRICITY U").

5.1.2.2 *Combustion of Wastewater Residuals*

Residuals from pulp and paper mill wastewater treatment plant (WWTP) operations are often burned in mill boilers both to recover energy and for solid waste minimization. Table 5.4 presents example characteristics of WWTP residuals that can affect their suitability for combustion. From this table, it can be seen that characteristics of residuals vary significantly. In this study, sensitivity analyses for residuals combustion were set to account for this variation.

Co-firing with bark in a stoker boiler was assumed; however, only the fraction of heat from the WWTP residuals was analyzed. Burning WWTP residuals is more difficult than burning bark mainly because of their high ash and low oxygen content. To compensate for the effects of higher ash and lower oxygen contents, the moisture of the residuals must be lower to produce the same efficiency in stoker boilers (Kraft and Orender 1993). Kraft and Orender (1993) suggested that for sludge to burn like bark, the equivalent of five moisture points must be compensated for in some way. Switching from all bark to all residuals is worth five equivalent moisture points and

- co-firing 90% bark with 10% sludge is worth 0.5 moisture points; and
- co-firing 80% bark with 20% sludge is worth 1.0 moisture point.

In this study, the latter, which is more conservative, was assumed. However, as mentioned above, only the heat fraction from the residuals was analyzed. Only stoker boilers were analyzed.

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[7] Heating value and emission factors for wood and wood residuals specified by USEPA are as follows: 15.38 mmBtu HHV/short ton @12% water, 93.80 kg CO$_2$/mmBtu, 3.2E-2 kg CH$_4$/mmBtu and 4.2E-3 kg N$_2$O/mmBtu.
[8] BioCO$_2$: biogenic CO$_2$.

Table 5.4 Characteristics of WWTP Residuals

Source	WWTP Residual Type Considered	Ash Content (%wt, dry basis)	Carbon Content (%wt, dry basis)	Water Content (%wt, wet basis)	Heat Content (GJ HHV/BDmT)*
Durai-Swami et al. (1991)	Recycled paper mill and kraft mill	5.5 - 18.9	50.0 - 59.4	49.5 - 62.4	20.6 - 24.1
James and Kane (1991)	Kraft mill	8.0	48.0	60.0	19.8
Nickull et al. (1991)	Clarifier and dredged from sulfite mill	1.9	48.7	66.6	20.1
Kraft (1994), Kraft and Orender (1991, 1993)	Deinking, pulp mill, unspecified	0.2 - 48.1	28.8 - 51.8	50 - 80	5.0 - 21.5
Aghamohammadi and Durai-Swamy (1993)	Recycled paper and cardboard	2.8 - 3.0	48.4 - 48.6	50 - 85	20.6 - 20.8
Douglas et al. (1994)	Deinking	31.9 - 33.2	32.7 - 38.2	42.7 - 68.6	12.3 - 15.3
Frederik et al. (1996)	Recycled paper mill	43.8	23.2	42.0	8.38
La Fond et al. (1997)	Secondary	N/Av	49.3	N/Av	23.1
European Commission (2001), Swiss Center for Life Cycle Inventories (2010), (Hischier 2007)	Mechanical, primary and secondary Deinking	36.4 - 67.3 (deink only)	19 - 35.8	25 - 70.6	2.6 - 8.6 GJ (LHV)
NCASI (2005) taken from a memorandum to USEPA (ERG 2002)	Bleached kraft, unbleached kraft, unbleached kraft colored, deinked, mechanical, groundwood, chemi-mechanical – mixed and secondary	9.9 - 49.8	N/Av	36.2 - 80.6†	7.6 - 18.1†
USEPA GHG Reporting Rule (2009, Tables C-1 and C-2)	Wastewater from paper mills	N/Av	N/Av	N/Av	20.3§
Woodruff et al. (2012)	Pulping, deinking	10 - 60	N/Av	N/Av	9.3 - 23.3
NCASI unpublished lab experiments	Bleached kraft combined, deinking combined, non-integrated combined, non-integrated primary, deinking primary	26.1 - 74.4	23.1 - 37.3	N/Av	N/Av

*When unknown, assumed to be HHV. †Includes dewatered and not dewatered residuals. ‡Assuming USEPA values are expressed in Btu HHV/lb. §According to USEPA, wood residuals means materials recovered from three principal sources: municipal solid waste (MSW); construction and demolition debris; and primary timber processing. Wood residuals recovered from MSW include wooden furniture, cabinets, pallets and containers, scrap lumber (from sources other than construction and demolition activities), and urban tree and landscape residuals. Wood residuals from construction and demolition debris originate from the construction, repair, remodeling and demolition of houses and non-residential structures. Wood residuals from primary timber processing include bark, sawmill slabs and edgings, sawdust, and peeler log cores. Other sources of wood residuals include, but are not limited to, railroad ties, telephone and utility poles, pier and dock timbers, wastewater process sludge from paper mills, trim, sander dust, and sawdust from wood products manufacturing (including resinated wood products residuals), and logging residuals.

Water content of WWTP residuals (primary and secondary treatment, deinking residuals) can vary widely; see Table 5.4. Residuals are typically mechanically dewatered. The general objective of dewatering is to remove water to the extent that the solids volume is reduced and the resulting residuals behave as a solid and not as a liquid. Residuals dewatering is accomplished at pulp and paper facilities by incorporating equipment and practices that result in increased WWTP residuals solids content. Employing residuals dewatering a) reduces the costs associated with residuals hauling, b) maximizes the use of remaining landfill capacity, c) makes residuals a more attractive fuel for combination fuel-fired boilers, and d) makes residuals more attractive for beneficial use opportunities (NCASI 2008). WWTP residuals can be dewatered using several technologies, of which belt filter presses and screw presses are the most frequently used in the US industry (NCASI 2008). Solids contents achievable using belt filter and screw presses are over 30% ($WC_R < 70\%$[9]) and 40% ($WC_R < 60\%$), respectively.

In this study, it was assumed that WWTP residuals were dewatered to 40% solids content, whether they were to be burned or landfilled, i.e., dewatering is assumed to happen both in the biomass and non-use systems. For this reason, dewatering was not included in the study. Ashes from residuals combustion were assumed to be landfilled on site. Landfilling of sludge ashes was modeled using the US-EI database (Disposal, wood ash mixture, pure, 0% water, to sanitary landfill/CH WITH US ELECTRICITY), assuming landfilling of wood ash could be taken as a proxy. Sensitivity analyses were performed on water content, heating value, and ash content. These are summarized in Table 5.5. Efficiencies have been derived from Figure 5.1 (assuming $WC_{WR} + 1\%$).

Table 5.5 Scenarios/Sensitivity Analyses for WWTP Residual Combustion

Parameter Analyzed		Value Analyzed
Water content (WC_R)	BC	60% (Eff =60%)
	Low	50% (Eff =66%)
	High	70% (Eff =53%)
Higher heating value (HHV)	BC	15 GJ/BDmT
	Low	10 GJ/BDmT
	High	20 GJ/BDmT
Ash content	BC	30%
	Low	10%
	High	50%

According to USEPA (2009) emission factors for wood and wood residuals should be used for WWTP sludge. However, the carbon content of WWTP residuals can vary significantly depending on the type of residuals. In this study, USEPA emission factors are used as a base case and sensitivity analyses are performed accommodate the variability in the carbon content of WWTP residuals. This is summarized in Table 5.6. It is also assumed that the higher carbon contents are associated with the higher HHVs.

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[9] WC_{WWTPR}: water content of WWTP residuals.

Table 5.6 Emission Factors for Burning WWTP Residuals

Parameter Analyzed			Value Analyzed
Biogenic CO_2	kg CO_2/BDmT	BC	1,807 (USEPA, CC = 49%)
		Low	697 (CC = 19%)
		High	2017 (CC = 55%)
CH_4	kg CH_4/BDmT	BC	0.617 (USEPA)
N_2O	kg N_2O/BDmT	BC	0.0809 (USEPA)

5.1.2.3 *Combustion of Paper Recycling Residuals (OCC Rejects)*

Paper recycling residuals, and more specifically OCC rejects, are often burned in boilers at pulp and paper mills that process recovered paper. This is done both for volume reduction and for energy recovery. Table 5.7 presents some general characteristics of OCC rejects, as well as the assumptions that were made in this study. OCC rejects were considered representative of the broader paper recycling residuals category. Ranges provided in the table are based on typical characteristics at a number of mills. They are intended to capture the breadth of anticipated variation for these materials.

Paper recycling residuals are a mix of fiber and plastic. In a stoker boiler, the fiber fraction is likely to behave as WWTP residuals (lower efficiency than that for wood biomass residuals). The plastic fraction is likely to behave like a fossil fuel (higher efficiency than that for woody biomass residuals). In this study, it was assumed that the boiler efficiency would be the same as that for woody biomass residuals at similar water content. Only stoker boilers were analyzed.

Ashes from residuals combustion were assumed to be landfilled on site. Landfilling of paper recycling residuals ashes was modeled using the US-EI database (Disposal, wood ash mixture, pure, 0% water, to sanitary landfill/CH WITH US ELECTRICITY), under the assumption that landfilling of wood ash could be taken as a proxy.

Table 5.7 General Characteristics of OCC Rejects and Sensitivity Analyses

Parameter		Range	Source	Range Analyzed in This Study		
				BC	Low	High
Fiber	% dry wt.	30 - 95	NCASI (2000)	60	30	90
Plastics	% dry wt.	5 - 70	NCASI (2000)	40	10	70
Ashes	% dry wt.	1 - 10	NCASI (2000)	5		
Biogenic CO_2 emissions when burning fiber fraction of OCC	kg CO_2/kg fiber	1.807*- 1.833†	(2009, Tables C-1 and C-2)	1.807	N/A	N/A
CH_4 emissions when burning fiber fraction of OCC	kg CH_4/kg fiber		Estimated*	6.17E-5*		
N_2O emissions when burning fiber fraction of OCC	kg N_2O/kg fiber		Estimated*	8.09-6*		
Fossil CO_2 emissions when burning plastic fraction	kg CO_2/kg plastic	2.30	US-EI (EarthShift 2009)‡	2.30		
CH_4 emissions when burning plastic fraction of OCC	kg CH_4/kg plastic	6.38E-6	US-EI (EarthShift 2009)‡	6.38E-6		
N_2O emissions when burning plastic fraction of OCC	kg N_2O/kg plastic	2.58E-5	US-EI (EarthShift 2009)‡	2.58E-5		
Higher heating value	GJ HHV/BDmT	18.8-27.7	NCASI (2000)	Fiber fraction: 19.1 Plastic fraction: 40.9		
Water content (boiler efficiency)	% wet wt. (%)	40-70	NCASI (2000)	55 (63)	40 (71)	70 (54)

* USEPA (2009) emission factors for wood and wood residuals, expressed based in physical units, are used for the fiber fraction of OCC rejects. † Assuming all carbon emitted as CO_2. ‡Disposal, plastics, mixture, 15.3% water, to municipal incineration/CH WITH US ELECTRICITY.

The carbon dioxide produced when plastics are burned is commonly accounted for using the same methods as for carbon dioxide produced in burning fossil fuels [USEPA 2010, Table C-1 and Section 98.33(e)]. For the gate-to-gate analyses of the biogenic GHG releases, it is only the accounting methods for biogenic carbon that are in question. For this reason, for these analyses, only the fiber fraction of paper recycling residuals was considered.

The heating values of the individual plastic and fiber fractions were presented in Table 5.7. There is no available information for the individual water contents of each of the fractions. However, it was shown in Table 5.7 that water content of paper recycling residuals varies significantly and it can be assumed that, while the plastic fraction of the residuals may contain some water, most of it would be found in the in the fiber fraction. In this analysis, the same water content as paper recycling residuals was applied to its fiber fraction. This resulted in 66% water for base case condition, which is very similar to WWTP residuals.

5.1.2.4   Combined Heat and Power (CHP)

In this study, a hypothetical combined heat and power configuration (CHP) representative of those commonly used in the forest products industry was modeled. This system, depicted in Figure 5.2, consisted of a biomass-fired boiler with high pressure steam routed to a back pressure turbine.

$$E_{DC} = S_{HP} + E_{Turb} = S_{HP} + S_{MP/LP} + P + L$$

$$S_{HP} + S_{MP/LP} + P = 1 \; GJ$$

Legend:
Q_R: Quantity of wood residues, E_{DC}: Usable energy from direct combustion,
E_{Turb}: Steam to turbine, S_{HP}: High pressure steam to process,
$S_{MP/LP}$: Extraction steam to process, P: Power, and L: Losses

Figure 5.2 Hypothetical CHP Configuration Considered in This Study

The relationship between Q_R and E_{DC} is described above in Section 5.1.2.1. Three scenarios were considered: 1) one representing an older pulp and paper mill (CHP1), 2) one representing a newer pulp and paper mill (CHP2), and 3) one considering the maximum power production through use of a condensing turbine. This last scenario could be considered representative of cases where very little steam is required. All three scenarios are presented in Table 5.8.

All the CHP scenarios were performed with base case stoker boiler conditions.

Table 5.8 CHP Scenarios

Scenario #	E_{DC}	E_{Turb}	S_{HP}	P	$S_{MP/LP}$	$S_{HP}+S_{MP/LP}$	L
				(GJ)			
CHP1	1.0499	0.9974	$0.05 \, E_{DC} =$ 0.0525	$0.18 \, E_{Turb} =$ 0.1795	$0.77 \, E_{Turb} =$ 0.7680	0.8205	$0.05 \, E_{Turb} =$ 0.0499*
CHP2	1.0499	0.9974	$0.05 \, E_{DC} =$ 0.0525	$0.29 \, E_{Turb} =$ 0.2892	$0.66 \, E_{Turb} =$ 0.6583	0.7108	$0.05 \, E_{Turb} =$ 0.0499*
CHP3	1.0499	0.9974	$0.05 \, E_{DC} =$ 0.0525	$0.95 \, E_{Turb} =$ 0.9475	0	0.0525	$0.05 \, E_{Turb} =$ 0.0499*

* Used for sootblowing.

5.1.2.5   Energy Production Using Fossil Fuels

Two possible options for producing energy from biomass residuals were considered: heat and combined heat and power. This means that an equivalent system needed to be studied regarding fossil fuels. For cases where the biomass energy system included heat production at the forest products facility, it was assumed that in the fossil fuel-based system an equivalent quantity of heat would be produced at the facility using either coal (A) or natural gas (B).

A somewhat different approach was taken for cases where combined heat and power would be applied to the biomass energy system. CHP configurations vary from facility to facility. In some cases, the turbines used to produce power receive steam from all boilers at the facility (i.e., both biomass and fossil fuel boilers). In other cases, they receive steam only from specific boilers (biomass or fossil fuel). Analyzing a case where the same amount of CHP would be achieved using biomass or fossil fuel boilers would have led to results that are very similar to those that were obtained for the case where it was assumed there was only heat produced because the only difference would have been due to energy losses in the CHP system, which are typically very small. Therefore, in this project, a more useful CHP scenario for comparison is one where there would be CHP production only in the biomass energy system; if biomass residuals were not used for energy production at forest products facilities, then the facility would have burned fossil fuel without CHP and would have to purchase the power from local utilities. Three scenarios were analyzed: C) US average electrical grid mix, D) power generated using coal, and E) power generated using natural gas combined cycle. These scenarios were selected in order to cover a large spectrum of possible mill situations.

All energy production processes from fossil fuel-related processes were modeled using the US-EI database. In specific, the following data sets were used for heat production:

- **Heat from coal:** "Bituminous coal, combusted in industrial boiler NREL/US" (this data set includes transportation of the coal to the boiler); and
- **Heat from natural gas:** "Natural gas, combusted in industrial boiler NREL/US" (this data set includes transportation of the natural gas to the boiler).

Both these data sets are expressed based on the quantity of fuel burned and not on the quantity of energy produced. To calculate the energy produced, the following was assumed (U.S. EPA 2009, Tables C-1):

- **Coal:** boiler efficiency of 85% and higher heating value of 24.93 MMBtu per short ton (29.0 GJ/tonne); and
- **Natural gas:** boiler efficiency of 80% and HHV of 1.028E-3 MMBtu per cubic feet (0.0383 GJ/m^3).

The following data sets were used for electricity production at utilities:

- Electricity, bituminous coal, at power plant NREL/US; and
- Electricity, natural gas, at turbine, 10MW/GLO WITH US ELECTRICITY.

The US average consumption grid mix was also modeled using processes from the US-EI Database. It was calculated by considering the quantity of power produced in the US by type of fuel, the quantity of power exported, and the quantity imported from Canada and Mexico. The production mix for the United States was calculated using 2010 data from the US Department of Energy, Energy Information Administration (EIA 2012, Forms EIA-906, EIA-920 and EIA-923). Data for 2009 from the International Energy Agency were used for Mexico (IEA 2013), as these were the most recently available. Since electricity imports from Mexico represent less than 3% of the total energy consumed in the US, these data are not expected to have a significant effect on the results. Canadian data were taken from Statistics Canada (2013a, b, c). Table 5.9 presents the fuel mix for US average electricity consumption as well as the US-EI data sets that were used to model it.

Table 5.9 US Average Electricity Grid Fuel Consumption Mix

Fuel Type	%	US-EI Data Set Used
Coal (including CHP)	45	Electricity, bituminous coal, at power plant NREL/US
Petroleum	1	Electricity, residual fuel oil, at power plant NREL/US
Natural gas (including CHP)	24	Electricity, natural gas, at power plant NREL/US
Nuclear	20	Electricity, nuclear, at power plant NREL/US
Hydroelectric	7	Electricity, hydropower, at power plant/SE WITH US ELECTRICITY U (89%), and Electricity, hydropower, at pumped storage power plant/US WITH US ELECTRICITY U (11%)
Wind	2	Electricity, at wind power plant/RER WITH US ELECTRICITY
Wood and wood derived fuels (CHP)	1	Electricity, biomass, at power plant NREL/US

Note that this US average grid mix was also used for the background electricity consumption of all processes modeled with the US-EI database.

Different fuels may be associated with different energy requirements for air emissions control of combustion units. In this study, it was assumed that the differences in energy requirements for emissions control were insignificant compared to the energy produced by the combustion units. This assumption was tested using sensitivity analyses.

5.1.3 Alternative Fates

5.1.3.1 Landfilling of Woody Mill Residuals

In landfills, a fraction of the biogenic carbon in forest products decays, primarily into gas. The remaining fraction is non-degradable under anaerobic conditions. This latter fraction varies by type of product. The degradable fraction of the biogenic carbon in landfills was assumed to decay according to a first order decay equation, with a variable rate constant, as presented in Table 5.10. Under anaerobic conditions, about one-half of the carbon is converted to biogenic CO_2 while the other half is converted to CH_4. Under aerobic conditions (e.g., in shallow unmanaged landfills), a much smaller fraction of the gas consists of CH_4. The methane correction factor, provided in Table 5.10, is used to adjust methane generation to reflect the extent of anaerobic conditions in different types of landfills.

Another important factor influencing the releases of landfill CO_2 and CH_4 methane to the atmosphere is the extent to which CH_4 is oxidized to biogenic CO_2 before exiting the landfill. Even in the absence of systems designed to capture and destroy methane, about 10% of the methane is oxidized as it moves through the surface layers of the landfill. Finally, some landfills are equipped with cover systems to collect and destroy methane by burning, and assumptions need to be made regarding the fraction of the methane that is collected and burned. It this study, it was assumed that wood residuals would be landfilled in an on-site mill landfill (i.e., no transportation required) and that for these mill landfills there was no methane capture, assumptions consistent with current practice in the industry.

Landfill parameters analyzed in this study are presented in Table 5.10.

Table 5.10 Parameters Affecting Emissions from Landfilling of Woody Mill Residuals

Parameter Analyzed	Value Analyzed		Source(s)
Biogenic carbon content (CC)	BC	50%	IPCC (IPCC 2006b)
Non-degradable carbon under anaerobic conditions (F_{CCND})	BC	55%	Wang et al. (2011)
	Low	45%	
	High	65%	
Decay rate (k)	BC	0.038 yr^{-1}	USEPA (2012), value representative of 52 US municipal solid waste landfills and various precipitation conditions
	Low	0.020 yr^{-1}	
	High	0.057 yr^{-1}	
Methane correction factor (MCF)	BC	1	IPCC (2006a), methane correction factors set up to be representative of managed anaerobic
Fraction of methane oxidized in landfill covers (F_{CH4OX})	BC	10%	IPCC (2006a)
Fraction of methane burned or oxidized (F_{CH4CB})	BC	0%	Assuming no mill landfill is equipped with methane collection systems

Cumulative quantities of carbon dioxide and methane emitted at a given time are calculated as follows.

Quantity of Carbon Converted to Gas at a Given Time:

$$Q_{C \rightarrow Gas} = Q_R \left(1 - e^{-kt}\right) \times MCF \times CC \times (1 - F_{CCND})$$

Where Q_R is the quantity of residuals required to produce a given amount of usable energy in the biomass product system and t the time in years.

Quantity of Carbon Converted to Methane ($Q_{C \rightarrow CH4}$):

$$Q_{C \rightarrow CH4} = Q_{C \rightarrow Gas} \times 0.5$$

Quantity of Methane Not Collected and Burned (Q_{CH4NCB})

$$Q_{CH4NCB} = Q_{C \rightarrow CH4} \times (1 - F_{CH4CB})$$

Quantity of Methane Released to the Environment ($Q_{CH4,Landfill}$):

$$Q_{CH4,Landfill} = Q_{CH4NCB} \times (1 - F_{CH4OX}) \times \frac{16}{12}$$

Quantity of Carbon Dioxide Released to the Environment ($Q_{CO2,Landfill}$):

$$Q_{CO2,Landfill} = \left(Q_{C \to Gas} - Q_{CH4,landfill} \times \frac{12}{16} \right) \times \frac{44}{12}$$

Other environmental loads related to landfilling activities were modeled using the US-EI database (Disposal, wood untreated, 20% water, to sanitary landfill/CH WITH US ELECTRICITY).

5.1.3.2   Incineration of Woody Mill Residuals

Incinerating the woody mill residuals without recovering the energy is not a very likely fate for these residuals. However, it was still modeled in this study as a way to illustrate the simplest way by which biogenic carbon can return to the atmosphere. Emissions from incineration are assumed the same as those for combustion for energy generation (see Section 5.1.2).

5.1.3.3   Landfilling of WWTP Residuals

Assumptions made to model GHG emissions from landfilling WWTP residuals are summarized in Table 5.11. Detailed calculations were presented in Section 5.1.3.1. Other environmental loads from landfilling of WWTP residuals were modeled using the US-EI database (Disposal, sludge from pulp and paper production, 25% water, to sanitary landfill/CH WITH US ELECTRICITY).

Table 5.11 Parameters Affecting Emissions from Landfilling of WWTP Residuals

Parameter Analyzed	Value Analyzed		Source(s)
Biogenic carbon content (CC)	BC	49%	See Table 5.5.
	Low	19%	
	High	55%	
Non-degradable carbon under anaerobic conditions (F_{CCND})	BC	50%	From NCASI unpublished experiments
	Low	40%	
	High	60%	
Decay rate (k)	BC	0.038	USEPA (2012), value representative of 52 US municipal solid waste landfills and various precipitation conditions
	Low	0.020	
	High	0.057	
Methane correction factor (MCF)	BC	1	IPCC (2006a), methane correction factors set up to be representative of managed anaerobic
Fraction of methane oxidized in landfill covers (F_{CH4OX})	BC	10%	IPCC (2006a)
Fraction of methane burned or oxidized (F_{CH4CB})	BC	0%	Assuming no mill landfill is equipped with methane collection systems

5.1.3.4   Incineration of WWTP Residuals

Emissions from incineration are assumed to be the same as those related to combustion for energy generation (see Section 5.1.2.2).

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5.1.3.5   Landfilling of Paper Recycling Residuals

Assumptions made to model GHG emissions from landfilling the fiber fraction of OCC rejects are summarized in Table 5.12. Detailed equations were provided in Section 5.1.3.1. Other environmental emissions related to the use of resources for landfilling the fiber fraction, as well as for landfilling the plastic fraction of OCC rejects, were modeled using the US-EI database:

- **Fiber fraction of residuals:** Disposal, sludge from pulp and paper production, 25% water, to sanitary landfill/CH WITH US ELECTRICITY, assuming WWTP residuals are representative of the fiber fraction of the paper recycling residuals, and
- **Plastic fraction of residuals:** Disposal, paper, 11.2% water, to sanitary landfill/CH WITH US ELECTRICITY.

Table 5.12 Parameters Affecting Emissions from Landfilling the Fiber Fraction of OCC Rejects

Parameter Analyzed	Value Analyzed		Source(s)
Biogenic carbon content (CC)	BC	50%	IPCC (2006a)
Non-degradable carbon under anaerobic conditions (F_{CCND})	BC	61%	NCASI (2004)
	Low	40%	
Decay rate (k)	BC	0.038	USEPA (2012), value representative of 52 US municipal solid waste landfills and various precipitation conditions
	Low	0.020	
	High	0.057	
Methane correction factor (MCF)	BC	1	IPCC (2006a), methane correction factors set up to be representative of managed anaerobic
Fraction of methane oxidized in landfill covers (F_{CH4OX})	BC	10%	IPCC (2006a), assuming no mill landfill is equipped with methane collection systems
Fraction of methane burned or oxidized (F_{CH4CB})	BC	0%	Assuming no mill landfill is equipped with a methane collection system

5.1.3.6   Incineration of Paper Recycling Residuals

Emissions from the incineration of paper recycling residuals were assumed to be the same as those related to combustion for energy generation (see Section 5.1.2.3).

5.2   Definition of Typical Scenarios

5.2.1   Current Energy Use and Waste Management Practices at Forest Products Facilities

Energy production and waste management data were compiled for the US forest products facilities (both pulp and paper and wood products) using data collected by AF&PA, NCASI, and the American Wood Council (AWC) and are summarized in Table 5.13 and Table 5.14. Most data are from 2010. Waste management data for the wood products facilities were compiled through 2008, only. For this reason, to produce a representative number for the entire forest products industry in 2010, the ratio of management options in 2008 was applied to 2010 production data. There are no "waste management"

data available for bark, sawdust and similar woody mill residuals produced at pulp and paper facilities, as they are not a waste but rather almost always being burned for energy.

Table 5.13 US Forest Products Facilities Estimated Fuel Mix
(Not Including Purchased Power and Steam)

Fuel Type	Paper Products Facilities	Wood Products Facilities	Forest Products Industry (AF&PA, NCASI and AWC members used as a proxy for the entire US industry)
	%		
Biomass fuels	**70.9**	**90.1**	**72.1**
Fossil fuels	**29.1**	**9.9**	**27.9**
Natural gas	13.9%	8.6%	13.5%
Coal	10.9%	0.3%	10.2%
Other fossil	4.4%	0.9%	4.1%
Power produced through combined heat and power	**GJ/GJ fuel input**	0.06	

Table 5.14 Waste Management Practices at US Forest Products Facilities

Waste Type	% Beneficial Use	Disposal		
		Total	% Landfill (% of disposal)	% Burning* (% of disposal)
Paper Products Facilities				
WWTP residuals	32.5%	67.5%	44.4% (65.8%)	23.1% (34.2%)
All others (causticizing wastes, general mill trash, construction debris, OCC rejects, landfilled broke, bark, wood residual, sawdust, knots, metal and other recyclable)	26.9%	73.1%	68.4% (93.6%)	4.7% (6.4%)
Wood Products Facilities				
All waste types (incl.: unusable sawdust, shavings, bark, garbage, recyclables, used oil, pallets, etc.)	96.2%	3.8%	3.8% (100%)	Negligible
Forest Products Industry (AF&PA and NCASI members used as a proxy for the whole US industry)				
Other waste from pulp and paper facilities and all waste from wood products facilities	57.8%	42.2%	39.6% (93.8%)	2.6% (6.2%)

*This does not include burning for energy.

Typical scenarios were modeled to be as representative as possible of current practices within US forest products manufacturing facilities using the information in the tables above. In addition, all parameters were set to their base case values for typical scenarios.

5.2.2 Woody Mill Residuals

The typical scenario considered for woody mill residuals is summarized in Table 5.15. A stoker boiler was assumed in the typical scenario as it is the most commonly used firing method for burning woody biomass (NCASI 2011a). Size reduction is sometimes required to process oversized particles prior to

burning. Stoker boilers can be used to burn biomass residuals for a broad spectrum of sizes (NCASI 2011a). Woody mill residuals are generally found in sizes suitable for stoker boilers (NCASI 2011a). For this reason, as a typical scenario, no size reduction was considered. The ratio of steam to power produced was set based on industry data for CHP (from AF&PA, NCASI, and AWC). This study analyzed only cases where CHP would be produced using biomass boilers and not fossil fuel boilers. Therefore, it was assumed that, at the industry level, the total power produced from CHP would be generated from biomass and fossil fuels in forest products facilities in the same ratio as overall fuel usage, and only the fraction from biomass was considered (5%). Turbine efficiency assumed for the CHP1 scenario above was assumed for the typical scenario as a conservative assumption. The actual heat/CHP configuration assumed for this system is depicted in Figure 5.3.

Figure 5.3 Heat/CHP Configuration Considered in the Typical Scenario for Woody Mill Residuals

The typical scenario considered was based on the data presented earlier in Table 5.13 for the entire forest products industry. It can be seen from this table than natural gas and coal are the main fossil fuels used by the US forest products industry. Therefore, in the typical scenario, only those two were considered in the ratio used by the industry. It was hence assumed that 57% of the steam produced from biomass would displace heat from natural gas and 43% would displace heat from coal. All (100%) of the displaced power was assumed to be from the US power consumption grid mix average. As shown previously in Table 5.14, when woody mill residuals are disposed of, they are either landfilled (94%) or burned (6%). However, as the burning reported by NCASI/AF&PA members most likely involves recovery of energy, this was not considered to be an alternative fate for the typical scenario. Instead, 100% landfilling was considered. It should be noted however, that there are very few data on what would be a reasonable "typical" alternative fate for woody mill residuals as it is not a common practice of the industry to dispose of these.

Table 5.15 Typical Scenario for Woody Mill Residuals

Pre-Processing			Energy Produced at Forest Products Facilities Using Biomass Residuals		Energy Produced at Forest Products Facilities or Utilities Using Fossil Fuels		Alternative Fate of Residuals		
SR0	No size reduction	100%	Heat from stoker boiler and residual steam from CHP	92%	Natural gas	57%	MR1	Landfill	100%
					Coal	43%			
SR1	Size reduction - Mobile chipper	0%	Power from CHP	8%	US average power consumption mix	100%	MR2	Incineration	0%
SR2	Size reduction - Stationary chipper	0%							

5.2.3   WWTP Residuals

The typical scenario considered for WWTP residuals is summarized in Table 5.16. A stoker boiler was also assumed in the typical scenario as a conservative assumption. The ratio of steam to power produced was set based on industry data (from AF&PA, NCASI, and AWC) regarding CHP. This study analyzed only cases where CHP would be produced using biomass boilers and not fossil fuel boilers. Therefore, it was assumed that, at the industry level, the total power produced from CHP would be generated from biomass and fossil fuels in forest products facilities in the same ratio as overall fuel usage and only the fraction from biomass was considered (5%). Turbine efficiency assumed for the CHP1 scenario above was used for the typical scenario as a conservative assumption. The actual heat/CHP configuration assumed for this system is depicted below in Figure 5.4.

Figure 5.4 Heat/CHP Configuration Considered in the Typical Scenario for WWTP Residuals

The typical scenario considered was based on the data presented in Table 5.13 for the whole industry. It can be seen from this table that natural gas and coal are the main fossil fuels used by the US forest products industry. In the typical scenario, therefore, only these two fuels were considered in the ratio used by the industry. It was hence assumed that 57% of the steam produced from biomass would

displace heat from natural gas and 43% would displace heat from coal. All (100%) of the displaced power was assumed to be from the US power consumption grid mix average. Finally, as shown previously in Table 5.14, WWTP residuals that are not beneficially used are typically landfilled (66%) or burned (34%). As it is not necessary that burning residuals would involve recovery of energy (for instance, in cases where the heating value would be too low), this ratio was assumed in the typical scenario.

Table 5.16 Typical Scenario for WWTP Residuals

Energy Produced at Forest Products Facilities Using Biomass Residuals		Energy Produced at Forest Products Facilities or Utilities Using Fossil Fuels		Alternative Fate of Residuals		
Heat from stoker boiler and residual steam form CHP	92%	Natural gas	57%	MR1	Landfill	66%
		Coal	43%			
Power from CHP	8%	US average power consumption mix	100%	MR2	Incineration	34%

5.2.4 Paper Recycling Residuals

The typical scenario considered for paper recycling residuals is summarized in Table 5.17. A stoker boiler was assumed in the typical scenario as a conservative assumption. The ratio of steam to power produced was set based on industry data (from AF&PA, NCASI, and AWC) for CHP. This study analyzed only cases where CHP would be produced using biomass boilers and not fossil fuels boilers. Therefore, it was assumed that, at the industry level, the total power produced from CHP would be generated from biomass and fossil fuels in forest products facilities in the same ratio as overall fuel usage and only the fraction from biomass was considered (5%). Turbine efficiency assumed for the CHP1 scenario above was used for the typical scenario as a conservative assumption. The actual heat/CHP configuration assumed for this system is depicted below in Figure 5.5.
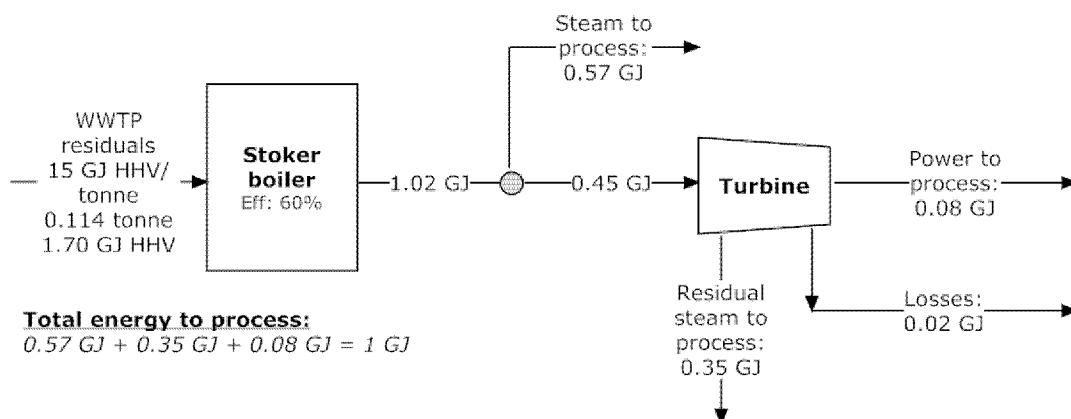

Figure 5.5 Heat/CHP Configuration Considered in the Typical Scenario for Paper Recycling Residuals

The typical scenario considered was based on the data presented above in Table 5.13 for the whole industry. It can be seen from this table than natural gas and coal are the main fossil fuels used by the US forest products industry. In the typical scenario, only those two were considered in the ratio used by the industry. It was hence assumed that 57% o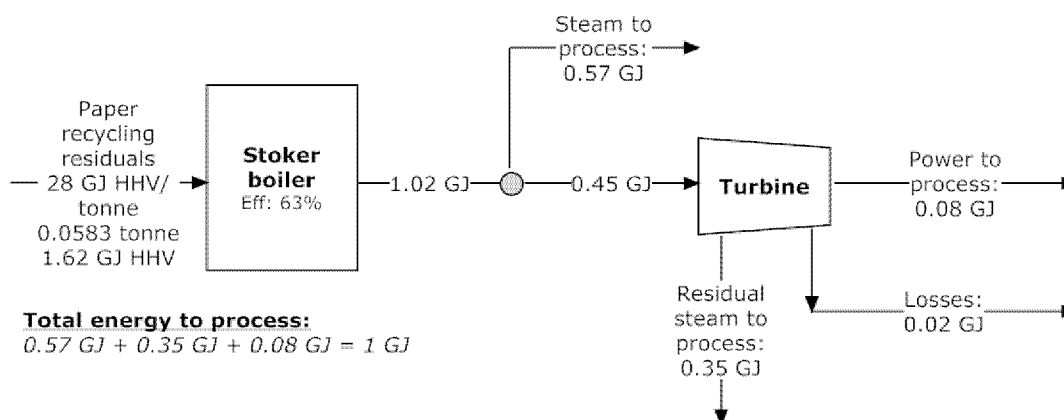f the steam produced from biomass would displace heat from natural gas and 43% would displace heat from coal. All (100%) of the displaced power was

assumed to be from the US power consumption mix average. Finally, as shown in Table 5.14, paper recycling residuals that are not beneficially used are typically landfilled (93.6%) or burned (6.4%). As it is not necessary that burning residuals would involve recovery of energy (for instance if they were disposed of in municipal facilities), this ratio was assumed in the typical scenario.

Table 5.17 Typical Scenario for Paper Recycling Residuals

Energy Produced at Forest Products Facilities Using Biomass Residuals		Energy Produced at Forest Products Facilities Or Utilities Using Fossil Fuels		Alternative Fate of Residuals		
Heat from stoker boiler and residual steam form CHP	92%	Natural gas	57%	MR1	Landfill	93.6%
		Coal	43%			
Power from CHP	8%	US average power consumption mix	100%	MR2	Incineration	6.4%

6.0   RESULTS AND DISCUSSION: CRADLE-TO-FINAL ENERGY

This section discusses the results of the cradle-to-final energy analysis, i.e., including fossil fuel substitution.

Note: For the GHGIs indicators, the results at 100 years of applying the dynamic carbon footprinting approach are compared with those obtained using the IPCC 100-year GWPs. Because the comparisons reveal that the differences at 100 years are small, for simplicity, the contribution, scenarios, and sensitivity analyses results are presented using only 100-year GWPs.

6.1   Woody Mill Residuals

This section presents the results for the woody mill residuals.

6.1.1   Typical Scenario: Base Case Results

The typical scenario was first analyzed with all parameters at their base case values.

6.1.1.1   *Greenhouse Gas Impact: Differential GHGI*

When using the dynamic carbon footprinting approach, the biomass energy system produces, after 100 years, a greenhouse gas impact that is **261 kg CO$_2$E lower**[10] per gigajoule of energy produced compared to the defined non-use system. This reduction is **254 kg CO$_2$E** when applying IPCC 100-year GWPs.

Figure 6.1 presents the 100-year differential GHGI for the biomass energy system compared to the non-use system as well as the contribution of each system component to the results using IPCC 100-year GWPs. In this figure,

- the GHGI indicator results from the non-biogenic CO$_2$ releases [which include fossil fuel-related CO$_2$, CH$_4$ and N$_2$O as well as biomass-related CH$_4$ and N$_2$O and all other GHGs
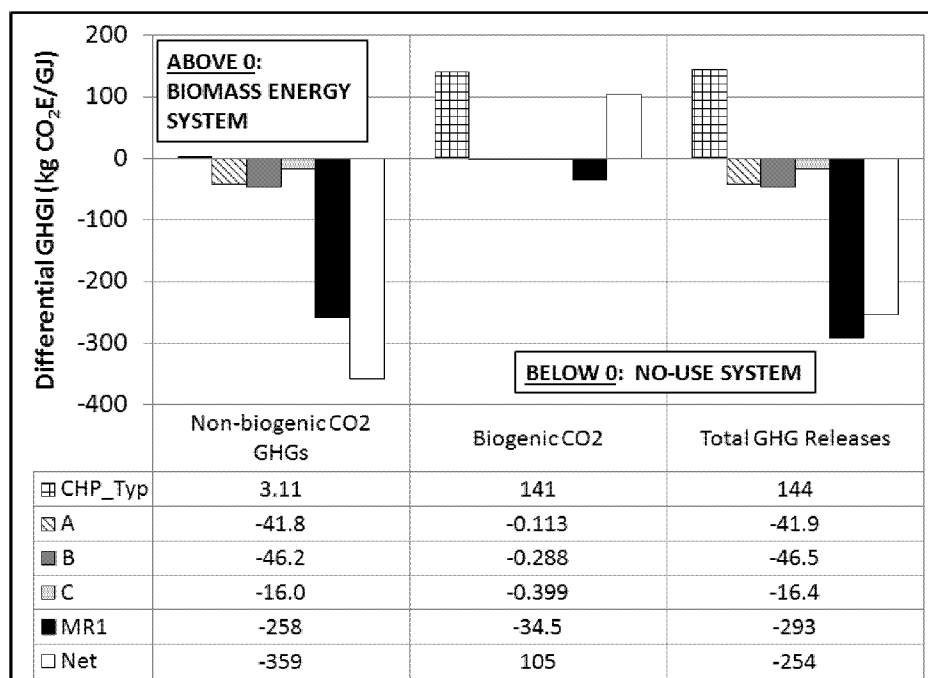
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[10] Results in this report are always presented as differences (i.e., biomass energy system minus non-use system). The "Relative GHGI" indicator does not include biogenic CO$_2$. The "Differential GHGI" indicator includes emissions and removals of biogenic CO$_2$.

(fossil fuel- and biomass-related)], the GHGI indicator results from biogenic CO_2 releases and the total GHG releases[11] are depicted separately;

- the results from the biomass energy system are shown as positive numbers;
- the results from the non-use system are shown as negative numbers (because they are avoided);
- the "net" bars represent the sum of the different system components; and
- a net positive indicates that the biomass energy system impacts are greater than the non-use system and a net negative indicates that the biomass energy system impacts are lower than the non-use system (in other words, the more net negative the indicator result, the more beneficial is the biomass energy system).

As shown in this figure, most of the difference between the biomass energy and non-use systems is attributable to non-biogenic CO_2 GHGs. More specifically, the methane emissions from landfills (most of MR1) avoided when burning residuals to produce energy is responsible for a large portion of the benefits from the biomass energy system. Reducing energy production from fossil fuels [i.e., heat from coal (A), heat from natural gas (B), and US average power grid (C)] also contributes to the difference, but to a lesser extent. The greenhouse gas impact caused by the emissions of biogenic CO_2 are different in the two systems (i.e., the net is not zero) for two reasons. First, much of the biogenic carbon is released as methane in the non-use system (included within non-biogenic CO_2 GHGs) and mostly as carbon dioxide in the biomass energy system. Second, some of the carbon is stored in landfills in the non-use system.

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[11] In this report, "Total GHG releases" is used as a short form for the sum of non-biogenic CO_2 GHGs and biogenic CO_2 GHGs.

	Non-biogenic CO2 GHGs	Biogenic CO2	Total GHG Releases
⊞ CHP_Typ	3.11	141	144
▨ A	-41.8	-0.113	-41.9
▤ B	-46.2	-0.288	-46.5
▦ C	-16.0	-0.399	-16.4
■ MR1	-258	-34.5	-293
☐ Net	-359	105	-254

Figure 6.1. Contribution Analysis for the Differential GHGI (at 100 Years) for Woody Mill Residuals - Typical Scenario
[In the figure, the different components of the biomass energy system are depicted as follows: CHP system as described in Figure 5.3 (CHP_Typ). The components of the non-use system are depicted as follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residuals in landfills (MR1). Results reflect the use of 100-year GWPs.]

6.1.1.2   Greenhouse Gas Impact: Relative Non-BioCO₂ GHGI

The result for the "Relative Non-BioCO$_2$ GHGs" indicator is -99.1%[12] for both the dynamic carbon footprinting approach and IPCC 100-year GWPs, meaning that the biomass product system generates almost no GHGs when ignoring biogenic CO$_2$.

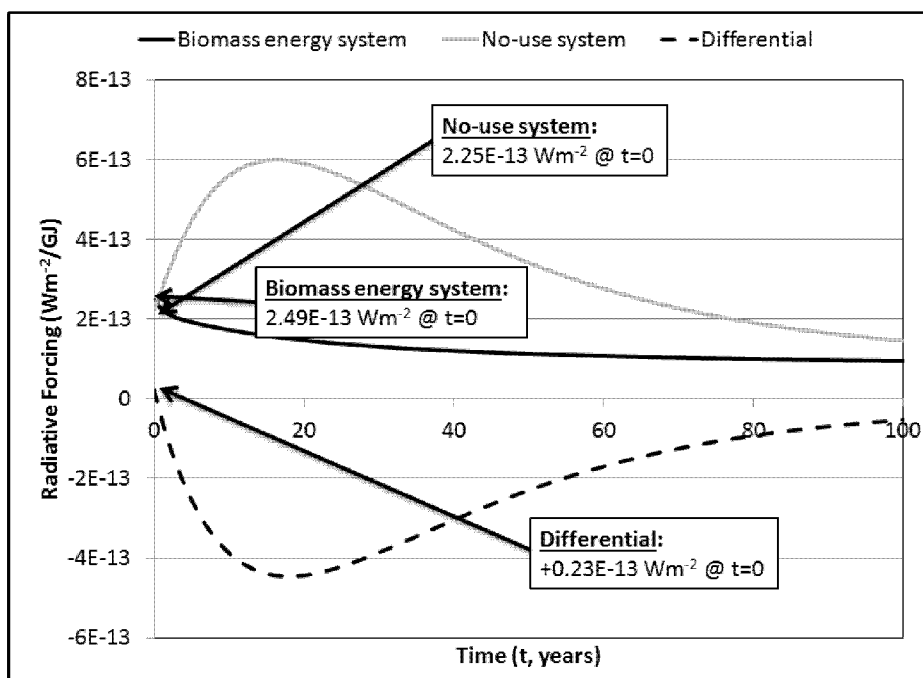### 6.1.1.3   Greenhouse Gases: Timing of Impacts

When residuals are burned for energy, the biogenic carbon is immediately released to the atmosphere. In contrast, residuals placed into landfills degrade relatively slowly, releasing the carbon (both CO$_2$ and CH$_4$) over time.

Figure 6.2 shows the annual radiative forcing attributable to greenhouse gas emissions from producing 1 GJ of energy in the biomass energy and non-use systems. These values have been calculated based on the dynamic radiative forcing approach, described in Section 4.1.6.1 of this report.[13] An explanation of the factors contributing to the radiative forcing is shown in Table 6.1.

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[12] Non-biogenic CO$_2$ GHGs only. Calculated as follows: (CHP_Typ - A - B - C - MR1)/(A+B+C+MR1).
[13] In Figure 6.2 and Figure 6.3, radiative forcing due to the GHG emissions is plotted in units of Wm^{-2} instead of units of CO$_2$E because, when using dynamic radiative forcing calculations, the relationship between annual and cumulative results is much easier to illustrate visually using units of Wm^{-2}. For other residuals addressed later in this report, only the differential cumulative results are shown.
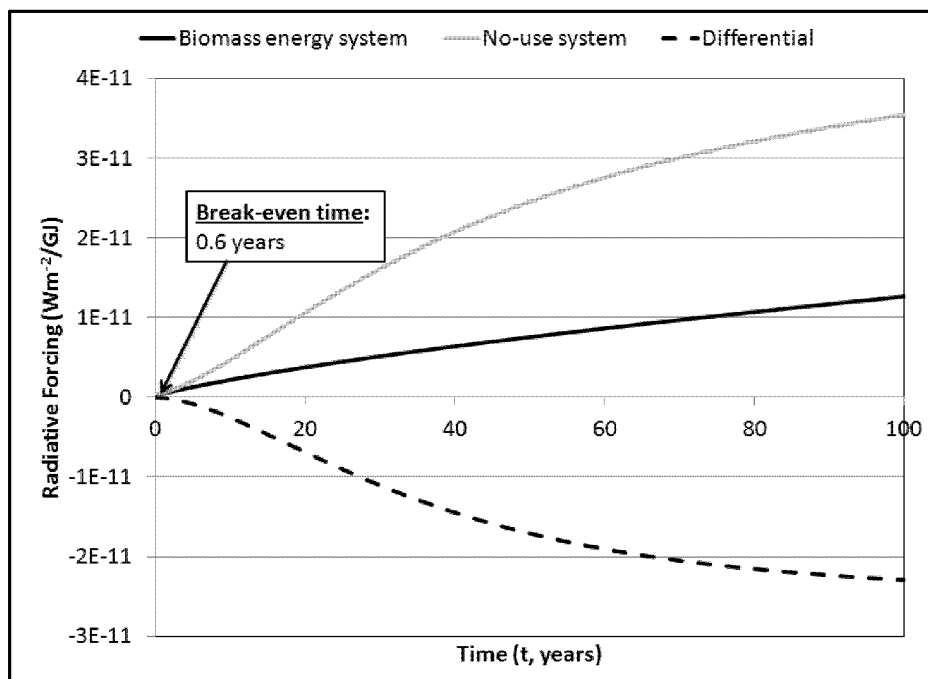
Figure 6.2 Annual GHG Impact for the Biomass Energy and Non-Use Systems:
Woody Mill Residuals - Typical Scenario

Table 6.1 Explanation of Annual Emissions, Woody Mill Residuals, Dynamic Carbon Footprinting

Time (years)	Biomass Energy System	Non-Use System	Differential (i.e., biomass energy system minus non-use system)
t = 0	The woody residuals are burned, releasing GHGs, which result in radiative forcing at the time of combustion of 2.49E-13 Wm^{-2}.	The fossil fuels are burned, releasing GHGs, which result in radiative forcing at the time of combustion of 2.25E-13 Wm^{-2}. Biomass residuals are placed in landfills. There are no releases from the landfills at time 0.	The differential radiative forcing is positive (0.23E-13 Wm^{-2}) because at time 0 there is more forcing from the emissions released by the biomass energy system than from the non-use system.
0 < t < ∞	There are no additional emissions from the biomass energy system. The radiative forcing caused each year by GHGs released in year 0 slowly declines as these GHGs degrade (e.g., CH$_4$) or are removed from the atmosphere (e.g., CO$_2$).	Although there are no additional emissions from combustion, residuals start degrading in landfills releasing GHGs. In each year, there is radiative forcing from landfill GHGs released in the current year plus forcing due to GHGs released in previous years that are still in the atmosphere. During the period that landfill emissions are high, annual radiative forcing increases because the forcing from new emissions increases faster than previously emitted GHGs are removed from the atmosphere. Over time, however, the GHG releases from landfills decline and approach zero and the GHGs in the atmosphere degrade (e.g., CH$_4$) or are removed from the atmosphere (e.g., CO$_2$). As a result, the annual radiative forcing approaches zero.	The differential radiative forcing goes through a minimum and then increases, approaching zero, because the emissions from both systems eventually degrade or are removed from the atmosphere.

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While Figure 6.2 shows the annual radiative forcing, Figure 6.3 shows the same data but plotted as cumulative radiative forcing, in units of Wm^{-2}, associated with emissions of GHGs in the biomass energy and non-use systems for woody mill residuals as a function of time. An explanation of the sources of this radiative forcing is provided in Table 6.2. Figure 6.3 shows that the differential radiative forcing is initially positive because the forcing due to the emissions from the biomass energy system is higher than that for the non-use system. The differential cumulative greenhouse gas impact quickly becomes negative, however, as landfill emissions increase in the non-use scenario. The figure shows that, under the typical scenario assumptions (e.g., alternative fate is 100% landfill), it takes 0.6 years before the cumulative radiative forcing due to GHG releases in the biomass energy system is less than the radiative forcing due to releases in the non-use system.
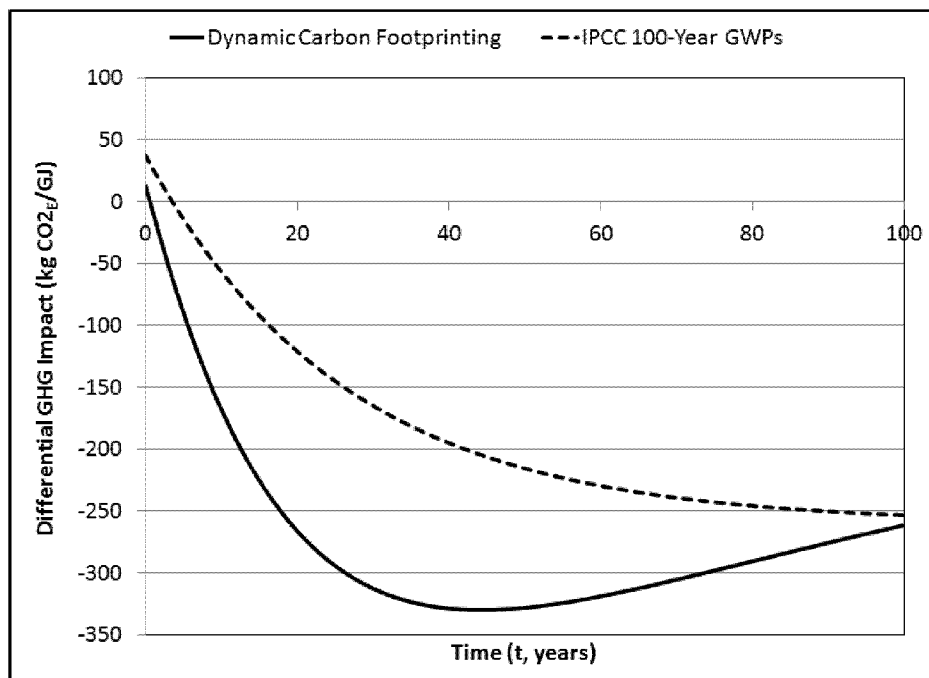

Figure 6.3 Cumulative GHG Impact for the Biomass Energy and Non-use Systems: Woody Mill Residuals - Typical Scenario

Table 6.2 Explanation of Cumulative Emissions, Woody Mill Residuals

Time (years)	Biomass Energy System	Non-Use System	Differential (i.e., biomass energy system minus non-use system)
t = 0	The woody residuals are burned, releasing GHGs, which result in radiative forcing at the time of combustion of 2.49E-13 Wm^{-2}.	The fossil fuels are burned, releasing GHGs, which result in radiative forcing at the time of combustion of 2.25E-13 Wm^{-2}. Biomass residuals are placed in landfills. There are no releases from the landfills at time 0.	The differential radiative forcing is positive (0.23E-13 Wm^{-2}) because at time 0, there is more forcing from the emissions released by the biomass energy system than from the non-use system.
0 < t < 0.6	There are no new emissions from the biomass energy system. The initially released GHGs remain in the atmosphere for a period of time, so each year, the cumulative radiative forcing increases.	Biomass residuals placed in landfills starts to degrade, releasing GHGs. The cumulative GHG emissions, and their cumulative radiative forcing, increase rapidly.	The difference in cumulative radiative forcing decreases as the forcing associated with the non-use system increases more rapidly that that associated with the biomass energy system.
t = 0.6	Cumulative radiative forcing reaches 3.9E-13 Wm^{-2}.	Cumulative radiative forcing reaches 3.9E-13 Wm^{-2}.	The cumulative differential radiative forcing is 0 (break-even time).
3.6 < t < ∞	There are no new emissions from the biomass energy system but cumulative forcing continues to increase until all GHGs are removed from the atmosphere.	The emissions from the landfill continue for a considerable period. Cumulative radiative forcing continues to increase until all GHGs released from fossil fuel combustion and from disposal operations are removed from the atmosphere.	At 100 years, the difference in cumulative radiative forcing is -2.29E-11 Wm^{-2}. The difference changes only slowly after this point.

Figure 6.4 compares the timing of differential cumulative GHGI results obtained using the dynamic carbon footprinting approach with those obtained using IPCC 100-year GWPs in units of kg CO_2E. The first observation that can be made from that chart is that the differential cumulative GHGI results decline faster when using the dynamic carbon footprinting approach than with IPCC GWPs. In other words, more short-term benefits from using biomass residuals for energy production are observed when applying dynamic carbon footprinting. The break-even time is 0.6 years using dynamic carbon footprinting and 3.6 years when using IPCC global warming potentials. The difference is due to the methane released from the landfills under the non-use scenario. Methane is a potent greenhouse gas but it has a short lifetime in the atmosphere so its greenhouse gas impact is concentrated in the years immediately following its release, as opposed to carbon dioxide, which is much more persistent.

Another difference is that, while the cumulative greenhouse gas impact is steadily going down to reach a plateau using IPCC GWPs, it goes through a minimum using the dynamic carbon footprinting approach. Again, this is because of the greater impact of methane emissions from the non-use scenario in the early years of the simulation. As the methane decomposes to CO_2, the results for dynamic modeling and 100-year GWPs become similar.

Figure 6.4   Emissions Timing: Comparing Results Based on Dynamic Carbon Footprinting and
IPCC 100-Year GWPs

6.1.1.4   Consumption of Fossil Fuels

Figure 6.5 shows the relative consumption of fossil fuels ("Relative FF CON," biomass energy
system compared to non-use system). It can be seen from the figure that fossil fuel use in the biomass
energy system is 100% lower; virtually no fossil fuels are used in the biomass energy system. It can
also be seen from the figure that the main contributor to the difference between the systems is the heat
from natural gas in the non-use system.

Figure 6.5 Relative Consumption of Fossil Fuels for Woody Mill Residuals - Typical Scenario
[In the figure, the different components of the biomass energy system are depicted as follows: CHP system as described in Figure 5.3 (CHP_Typ). The components of the non-use system are depicted as follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residual in landfills (MR1).]

6.1.2   Typical Scenario: Perturbation and Sensitivity Analyses

6.1.2.1   *Perturbation Analyses*

As mentioned in Section 4.1.3, sensitivity ratios represent the percent change in an output variable caused by a 1% change in one given input variable. For simplicity and given that the GHGI results do not vary significantly over a 100-year period depending on the approach used, perturbation analyses were performed using IPCC 100-year GWPs. Figure 6.6 shows the sensitivity ratios for the four indicators analyzed in this study, for woody mill residuals. The following input variables were tested in sensitivity analyses: transportation distance of the residuals (Distance), their water content (WC_R), their heating value (HHV), and the fraction of their carbon content that is non-degradable carbon (F_{CCND}).

The results depicted in Figure 6.6 should be interpreted as follows. A sensitivity ratio of +1.0 means that value of the output variable increases by 1% when the input variable value is increased by 1%. The greater the absolute value of the sensitivity ratio, the more intrinsically sensitive a parameter was.

It can be seen from Figure 6.6 that transportation distance of residuals to the boiler had very little effect on the "Differential GHGI" indicator results when compared to the other studied parameters. The fraction of non-degradable carbon (F_{CCND}) had the most significant effect on the results, with sensitivity ratios of 1.4. The positive ratio means that when increasing the value of the parameter, the indicator result is also increased, indicating a declining performance of the biomass energy system compared to the non-use system. Increasing the water content of the residuals, and thus reducing the boiler efficiency, produced a negative sensitivity ratio, i.e., a positive effect on the results. This is because on a per gigajoule basis, more residuals are required to produce the energy and thus more

landfilling, and associated methane emissions from landfills, are avoided. The opposite can be seen when increasing the higher heating value.

The time for biomass energy system to have lower cumulative emissions than the non-use system ("break-even time" in Figure 6.6) was significantly affected, relatively speaking, by the various parameters analyzed, except for the transportation distance of residuals.

Finally, overall, the relative GHGI and relative fossil fuel consumption indicator results were not significantly affected by the parameters analyzed.

Figure 6.6 Sensitivity Ratios for Woody Mill Residuals

6.1.2.2   ***Sensitivity Analyses***

Above, perturbation analyses were applied to determine which parameters were intrinsically the most sensitive to the results without considering the actual ranges of possible values for these parameters. In Table 4.1, the results of sensitivity analyses considering the actual possible ranges of variation for each parameter are presented. It is shown that the range of possible heating values for woody mill residuals had the most effect on the results. Also, even with the highest heating value for residuals, the GHG benefits of the biomass energy system compared to the non-use system are still considerable.

Table 6.3 Sensitivity Analyses on Indicator Results for the Typical Scenario, Woody Mill Residuals

Para-meter	Differential GHGI* (kg CO$_2$E/GJ)			Relative Non-BioCO$_2$ GHGI* (%)			Break-Even Time* (years)			Relative FF CON (%)		
	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max
WC$_R$		-229	-268		-99.1	-99.2		0.9	2.5		-100	-100
HHV		-219	-334		-99.0	-99.2		0.3	3.9		-100	-100
F$_{CCND}$	-254†	-254	-318	-99.1 $\ddagger$	-99.1	-99.3	3.6 §	1.6	4.7	-100	-100	-100
Transp. of residuals		-252	-254		-99.1	-99.1		2.1	3.6		-100	-100
k		-254	-254		-99.1	-99.1		2.5	7.0		-98.2	-100

*Computed using IPCC 100-Year GWPs. †-261 kg CO$_2$E/GJ using dynamic modeling of cumulative radiative forcing. $\ddagger$ -99.1% using dynamic modeling of cumulative radiative forcing. §0.6 years using dynamic modeling of cumulative radiative forcing.

6.1.3   System Configuration Scenarios

In Section 5.0, various system configuration scenarios were presented. For instance, it was noted that the alternative fate of woody mill residuals was difficult to determine. While the typical scenario assumed 100% landfilling, it might well be incineration. System configuration scenarios were used to analyze those system configuration assumptions that are uncertain.

All possible scenario combinations presented in Section 5.1 were analyzed (132 combinations). The calculations were performed using IPCC 100-year GWPs. Results are presented in Table 6.4 for cases where parameters would be at their base case value. GHG releases and fossil fuel consumption are significantly lower for all cases. Maximum differences were obtained in cases in which

- there is no size reduction;
- combined heat and power with maximum power production is produced;
- coal is being displaced (for both heat and power production);
- there is no transportation; and
- alternative fate is landfilling.

Minimum differences were obtained in cases in which

- there is size reduction;
- only heat is produced;
- natural gas is being displaced (for both heat and power production);
- there is transportation; and
- alternative fate is incineration.

Results in Table 6.4 also show that the time for the biomass energy system to have lower cumulative emissions than the non-use system varies between 0 and 4.5 years, the lowest being observed when incineration is the alternative fate.

Table 6.4 Indicator Results for Various System Configuration Scenarios, Woody Mill Residuals

Indicator	Unit	Typical	Min	Max
Differential GHGI*	kg CO_2E/GJ	-254†	-78.4	-458
Relative non-BioCO$_2$ GHGI*	%	-99.1‡	-94.9	-99.4
Break-even time*	years	3.6§	0	4.5
Relative FF CON	%	-100%	-98.5	-100

*Computed using IPCC 100-Year GWPs. † -261kgCO$_2$E/GJ using dynamic modeling of cumulative radiative forcing. ‡ -99.1% using dynamic modeling of cumulative radiative forcing. §0.6 years using dynamic modeling of cumulative radiative forcing.

6.2   WWTP Residuals

This section presents results for the WWTP residuals.

6.2.1   Typical Scenario: Base Case Results

The typical scenario was first analyzed with all parameters at their base case values.

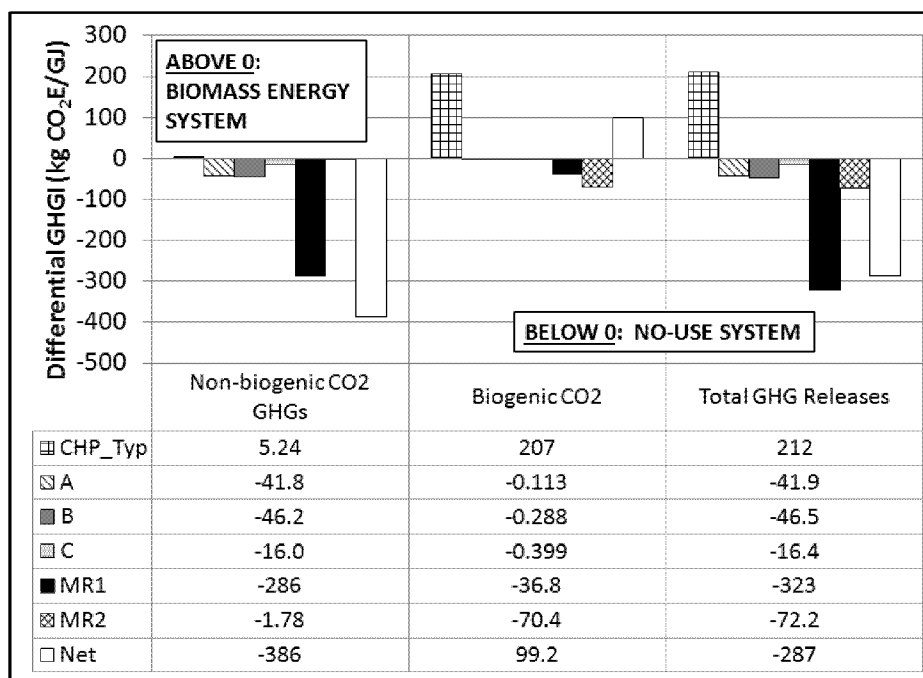#### 6.2.1.1   *Greenhouse Gases: Differential GHGs*

When using the dynamic carbon footprinting approach, the biomass energy system produces, after 100 years, a greenhouse gas impact that is **295 kg CO_2E lower**[14] per gigajoule of energy produced compared to the defined non-use system. This reduction is **287 kg CO_2E** when applying IPCC 100-year GWPs.

Figure 6.7 presents the 100-year differential GHGI for the biomass energy system compared to the non-use system as well as the contribution of each system component to the results using IPCC 100-year GWPs. In this figure, emissions from the non-use system are shown as a negative number because to obtain the Differential GHGs indicator overall result, the emissions of the non-use scenario were subtracted from those of the biomass energy system.

The figure shows that non-biogenic CO_2 GHGI is mostly lower because when burning residuals to produce energy, there are no methane emissions from landfills. The fact that there is less heat generated from fossil fuels also contributes to the lower impact, but to a lesser extent. Emissions of biogenic CO_2 are different in the two systems for two reasons. First, much of the biogenic carbon is released as methane in the non-use system (included within non-biogenic CO_2 GHGs) and mostly as CO_2 in the biomass energy system. Second, some of the carbon is stored in landfills in the non-use system.

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[14] Results in this report are always presented as differences (i.e., biomass energy system minus non-use system). The "Relative GHGI" indicator does not include biogenic CO_2. The "Differential GHGI" indicator includes emissions and removals of biogenic CO_2.

	Non-biogenic CO2 GHGs	Biogenic CO2	Total GHG Releases
⊞ CHP_Typ	5.24	207	212
⊠ A	-41.8	-0.113	-41.9
▣ B	-46.2	-0.288	-46.5
▦ C	-16.0	-0.399	-16.4
■ MR1	-286	-36.8	-323
⊠ MR2	-1.78	-70.4	-72.2
☐ Net	-386	99.2	-287

Figure 6.7 Contribution Analysis for the Differential GHGI (at 100 Years)
for WWTP Residuals - Typical Scenario
[In the figure, the different components of the biomass energy system are depicted as follows: CHP
system as described in Figure 5.4 (CHP_Typ). The components of the non-use system are depicted as
follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residual in
landfills (MR1), incineration of residuals (MR2). Results reflect the use of 100-year GWPs.]
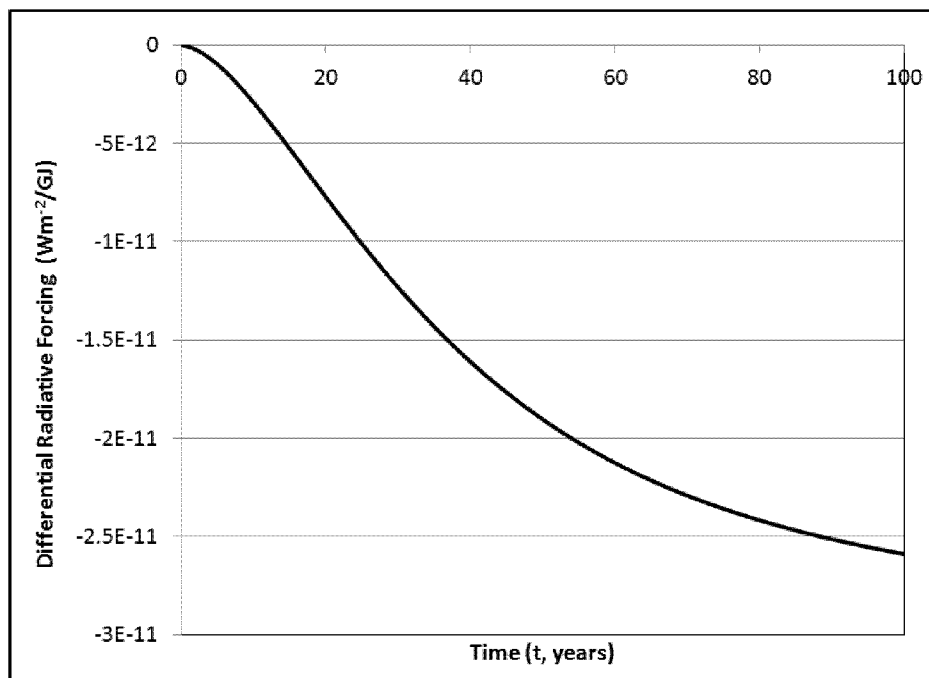
6.2.1.2 *Greenhouse Gases: Relative Non-BioCO₂ GHGs*

The result for the "Relative Non-BioCO$_2$ GHGs" indicator is -98.7%[15] (-99.1% using IPCC GWPs),
meaning that the biomass energy system generates almost no GHGs when ignoring biogenic CO$_2$ and
hence, produces a significant reduction when compared to the non-use system.

6.2.1.3 *Greenhouse Gases: Timing of Impacts*

When WWTP residuals are burned for energy, the related biogenic carbon is released to the
atmosphere immediately. In contrast, WWTP residuals placed into landfills degrade slowly, releasing
the related biogenic carbon (both CO$_2$ and CH$_4$) over time. Figure 6.8 presents the results of the
"Differential GHGI" indicator over time using USEPA's decay rates for materials placed in municipal
landfills, for the typical scenario. These results were developed using the dynamic carbon footprinting
approach described in Section 4.1.6.1 of this report and are expressed in units of radiative forcing
(Wm^{-2}). The net difference is initially negative (i.e., the impact from the biomass energy system is
lower than that from the no-use system from time equals zero, meaning that the break-even time is
zero) and then declines over time as the material degrades in landfills. When using IPCC 100-year
GWPS, the difference in impact is initially positive and the break-even time is observed at 1.8 years.

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[15] Non-biogenic CO$_2$ GHGs only. Calculated as follows: (CHP_Typ - A - B - C - MR1- MR2)/
(A+B+C+MR1+MR2).

Figure 6.8 Cumulative Differential GHGI Indicator Results as a Function of Time
for WWTP Residuals - Typical Scenario

6.2.1.4 *Consumption of Fossil Fuels*

Figure 6.9 shows the results for the relative consumption of fossil fuels indicator ("Relative FF CON," biomass energy system compared to non-use system).

It can be seen from Figure 6.9 that the biomass energy system used 99.3% less fossil fuel when compared to the non-use system defined in this study. This is due to the fact that virtually no fossil fuels are used in the biomass energy system. It can also be seen from the figure that the main contributor to the lower emissions is avoided heat from natural gas.
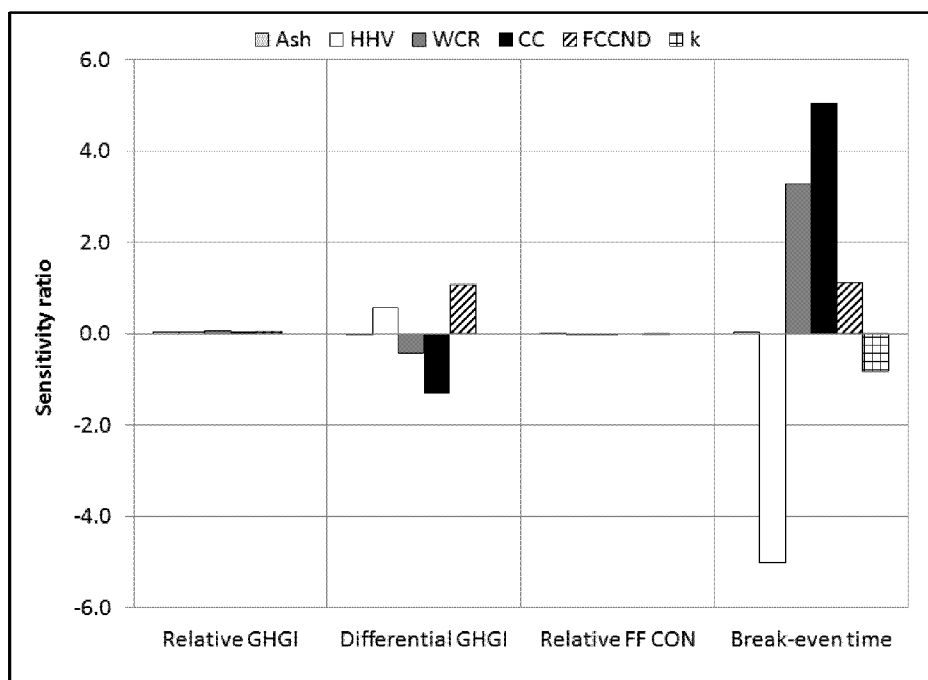
Figure 6.9 Relative FF CON Indicator Results for WWTP Residuals - Typical Scenario
[In the figure, the different components of the biomass energy system are depicted as follows: CHP
system as described in Figure 5.4 (CHP_Typ). The components of the non-use system are depicted as
follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residual in
landfills (MR1), incineration of residuals (MR2).]

6.2.2   Typical Scenario: Perturbation and Sensitivity Analyses

6.2.2.1   Perturbation Analyses

Various parameters were analyzed in perturbation analyses. For each of these parameters, a sensitivity
ratio was calculated (see Section 4.1.3). For simplicity and given that the GHGI results do not vary
significantly over a 100-year period depending on the approach used, perturbation analyses were
performed using IPCC 100-year GWPs.

Sensitivity ratios for the parameters tested in this study are presented in Figure 6.10. It can be seen
from that figure that the carbon content of the residuals has the most significant effect on the GHGI
results, with a sensitivity ratio of -1.3. The negative ratio means that when increasing the value of the
parameter, the score is decreased, indicating an improving performance of the biomass energy system
compared to the non-use system. The fraction of non-degradable carbon (F_{CCND}) also has significant
effect on the Differential GHGs results, with sensitivity ratio of 1.1. The positive ratio means that
when increasing the value of the parameter, the score is also increased, indicating a declining
performance of the biomass energy system compared to the non-use system. Increasing the water
content of the residuals, and thus reducing the boiler efficiency, produced a negative sensitivity ratio,
i.e., a positive effect on the results. This is because on a per gigajoule basis, more residuals are
required to produce the energy; thus, more landfilling and associated methane emissions from
landfills are avoided. The opposite can be seen when increasing the higher heating value. Overall,
Relative GHGs and fossil fuel consumption results were not significantly affected by the parameters
analyzed. Break-even time was shown, relatively speaking, to be highly sensitive to all parameters
tested, with the exception of the ash content.

Figure 6.10 Sensitivity Ratios for WWTP Residuals

6.2.2.2   Sensitivity Analyses

Above, perturbation analyses were applied to determine which parameters were intrinsically the most sensitive to the results without considering the actual ranges of possible values for these parameters. In Table 6.8, the results of sensitivity analyses considering the actual possible ranges of variation for each parameter are presented. It is shown that the range of possible heating values and carbon content for WWTP residuals had the most effect on the results. Also, even in the worst conditions, the GHG benefits of the biomass energy system compared to the non-use system are still considerable.

Table 6.5 Sensitivity Analyses on Indicator Results for the Typical Scenario, WWTP Residuals

Para-meter	Differential GHGI* (kg CO₂E/GJ)			Relative Non-BioCO₂ GHGI* (%)			Break-Even Time* (years)			Relative FF CON (%)		
	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max
WC$_R$		-271	-311		-98.6	-98.7		1.0	3.0		-99.2	-99.4
HHV		-242	-378		-98.5	-98.8		0	5.6		-99.0	-99.5
Ash	-287†	-287	-288	-99.1 ‡	-98.5	-98.8	1.8§	1.9	3.0	-99.3	-98.8	-99.8
CC		-182	-309		-97.7	98.8		0	3.0		-99.3	-99.3
F$_{CCND}$		-217	-287		-98.7	-98.7		1.6	2.4		-99.3	-99.3
k		-287	-287		-98.7	-98.7		1.3	3.5		-99.3	-99.3

*Computed using 100-year GWPs. †-295 kg CO₂E/GJ using dynamic modeling of cumulative radiative forcing.
‡-98.7% using dynamic modeling of cumulative radiative forcing. §0.0 years using dynamic modeling of cumulative radiative forcing.

6.2.3   System Configuration Scenarios

In Section 5.0, various system configuration scenarios were presented. All relevant scenario combinations were analyzed (40 combinations). Results are presented in Table 6.6 for cases where parameters would be at their base case, worst, or best values. Results obtained for the typical scenarios are also reproduced in this table for comparison purposes. GHG releases and fossil fuel consumption are significantly lower for all cases. Maximum differences were obtained in cases in which

- combined heat and power with maximum power production is produced;
- coal is being displaced (for both heat and power production); and
- alternative fate is landfilling.

Minimum differences were obtained in cases in which

- only heat is produced;
- natural gas is being displaced (for both heat and power production); and
- alternative fate is incineration.

Table 6.6 Indicator Results for Various System Configuration Scenarios - WWTP Residuals

Indicator	Unit	Typical	Min	Max
Differential GHGI*	kg CO_2E/GJ	-287**	-79.5	-589
Relative Non-BioCO$_2$ GHGs *	%	-99.1	-93.9	-99.3
Break-even time*	years	1.8§	0	6.4
Relative FF CON	%	-99.3	-99.1	-99.7

*Computed using 100-year GWPs.†-295 kg CO_2E/GJ using dynamic modeling of cumulative radiative forcing. ‡-98.7% using dynamic modeling of cumulative radiative forcing. §0.0 years using dynamic modeling of cumulative radiative forcing

6.3   Paper Recycling Residuals

6.3.1   Typical Scenario: Base Case Results

The typical scenario was first analyzed with all parameters at their base case values.

6.3.1.1   Greenhouse Gases: Differential GHGs

When using the dynamic carbon footprinting approach, the biomass energy system produces, after 100 years, a greenhouse gas impact that is **112 kg CO_2E lower**[16] per gigajoule of energy produced compared to the defined non-use system. This reduction is **109 kg CO_2E** when applying IPCC 100-year GWPs.

Figure 6.11 shows that the non-biogenic CO_2 GHGI is mostly lower because when burning residuals to produce energy, there are no methane emissions from landfills. Alone, the avoided methane emissions from landfills lower the impact by 154 kg CO_2E/GJ. The fact that there is less heat from

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[16] Results in this report are always presented as differences (i.e., biomass energy system minus non-use system). The "Relative GHGI" indicator does not include biogenic CO_2. The "Differential GHGI" indicator includes emissions and removals of biogenic CO_2.

fossil fuels also contributes to the lower impact, but to a lesser extent. Emissions of biogenic CO_2 are different in the two systems for two reasons. First, much of the biogenic carbon is released as methane in the non-use system (included within non-biogenic CO_2 GHGs) and mostly as CO_2 in the biomass energy system. Second, some of the carbon is stored in landfills in the non-use system.

	Non-biogenic CO2 GHGs	Biogenic CO2	Total GHG Releases
CHP_Typ	55.29	63	119
A	-41.8	-0.113	-41.9
B	-46.2	-0.288	-46.5
C	-16.0	-0.399	-16.4
MR1	-101	-12.7	-114
MR2	-4.24	-4.0	-8.3
Net	-154	45.7	-109

Figure 6.11 Contribution Analysis for the Differential GHGI (at 100 Years)
for Paper Recycling Residuals - Typical Scenario
[In the figure, the different components of the biomass energy system are depicted as follows: CHP system as described in Figure 5.5 (CHP_Typ). The components of the non-use system are depicted as follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residual in landfills (MR1), incineration of residuals (MR2). Results reflect the use of 100-year GWPs.]
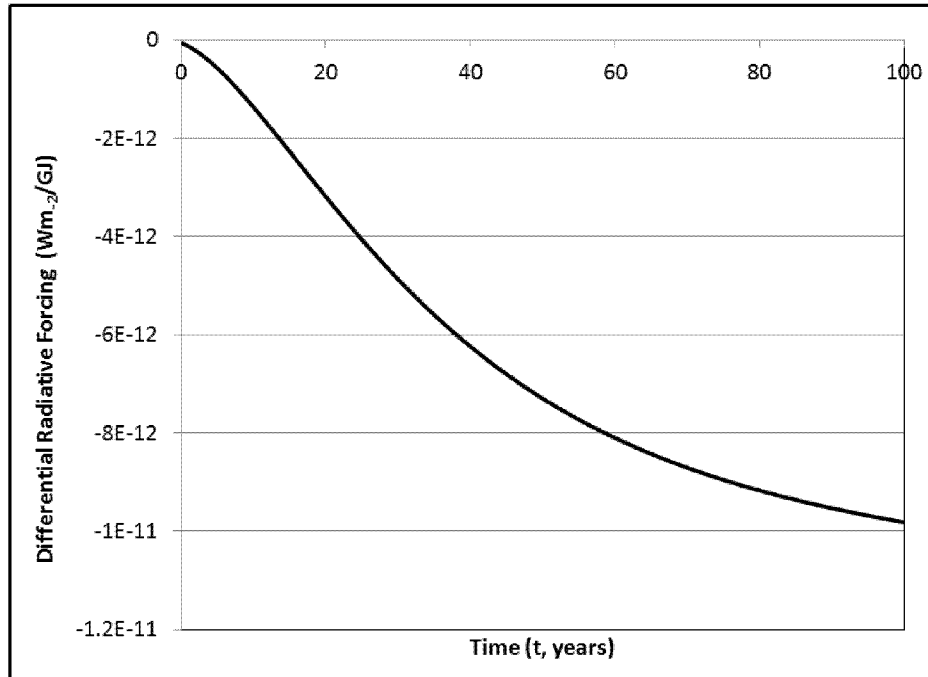
6.3.1.2   Greenhouse Gases: Relative Non-BioCO₂ GHGs

The result for the "Relative Non-BioCO$_2$ GHGI" indicator is -86.4%[17] (-75.2% when using IPCC GWPs), meaning that the biomass product system generates almost no GHGs when ignoring biogenic CO_2. When compared to other types of residuals presented above (woody mill residuals and WWTP residuals), the use of paper recycling residuals presents significantly lower overall benefits. This is because paper recycling residuals are composed of an important fraction of plastic which, when combusted, releases fossil fuel GHGs.

6.3.1.3   Greenhouse Gases: Emissions Timing

When paper recycling residuals are burned for energy, the biogenic carbon (both CO_2 and CH_4) is immediately released to the atmosphere. In contrast, residuals placed into landfills degrade slowly, releasing the carbon over time. Figure 6.12 analyzes the "Differential GHGI" indicator results over

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[17] Non-biogenic CO_2 GHGs only. Calculated as follows: (CHP_Typ - A - B - C - MR1 - MR2)/
(A+B+C+MR1+MR2).

time using USEPA's decay rate for materials placed in municipal landfills for the typical scenario. It shows that the differential impact is initially slightly negative (i.e., the impact from the biomass-based system is lower than that from the fossil fuel-based system, meaning that the break-even time is zero) and declines over time as the material degrades in landfills. When using the IPCC GWPs, the break-even time is also zero years.

Figure 6.12 Cumulative Differential GHGI Indicator Results as a Function of Time
for Paper Recycling Residuals - Typical Scenario

6.3.1.4 ***Consumption of Fossil Fuels***

Figure 6.13 shows the relative consumption of fossil fuels ("Relative FF CON," biomass energy system compared to non-use system) for paper recycling residuals.

It can be seen from that figure that the biomass energy system uses 99.9% less fossil fuel than the non-use system. This is due to the fact that virtually no fossil fuels are used in the biomass energy system. It can also be seen from the figure that the main contributor to the lower emissions is avoided heat from natural gas. Note that the plastic fraction of paper recycling residuals was not considered to be fossil fuel.

Figure 6.13 Relative Consumption of Fossil Fuels for Paper Recycling Residuals - Typical Scenario [In the figure, the different components of the biomass energy system are depicted as follows: CHP system as described in Figure 5.5 (CHP_Typ). The components of the non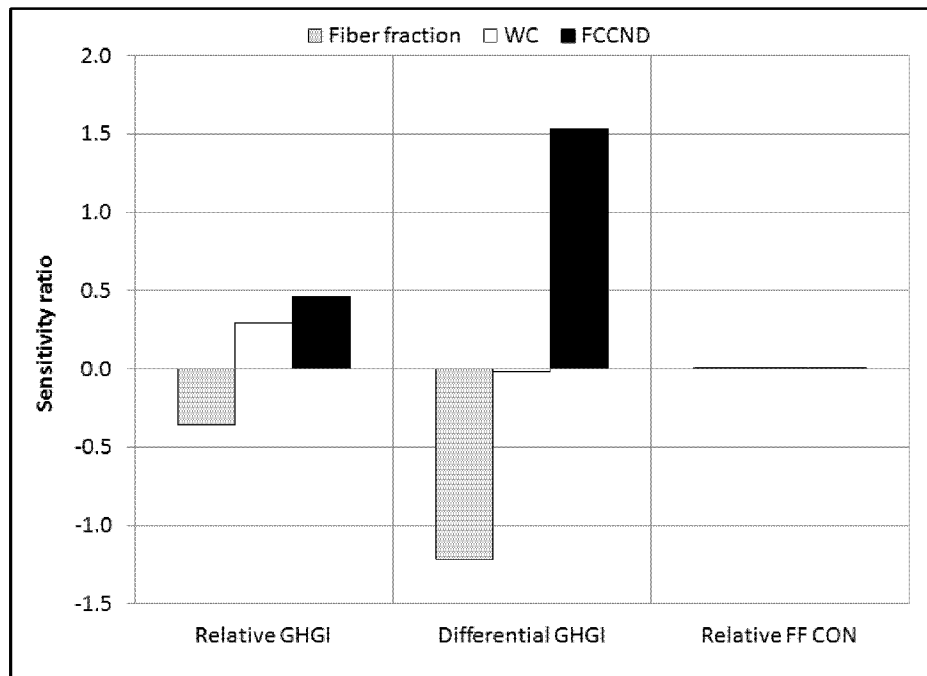-use system are depicted as follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residual in landfills (MR1), incineration of residuals (MR2).]

6.3.2   Typical Scenario: Perturbation and Sensitivity Analyses

6.3.2.1   *Perturbation Analyses*

Various parameters were analyzed in perturbation analyses. For each of these parameters, a sensitivity ratio was calculated (see Section 4.1.3). Sensitivity ratios for the parameters tested in this study are presented in Figure 6.14. Sensitivity ratios are not shown for break-even times as they were initially zero. It can be seen from Figure 6.14 that the fraction of non-degradable carbon (F_{CCND}) and the fiber fraction of paper recycling residuals have the most significant effect on the results, with sensitivity ratios up to 1.5. The positive ratio obtained for F_{CCND} means that when increasing the value of the parameter, the score is also increased, indicating a declining performance of the biomass energy system compared to that of the non-use system. Increasing the fiber fraction resulted in a negative sensitivity ratio. This means the biomass energy system generated lower emissions or consumed less fossil fuel than the non-use system. The water content of the residuals had little effect on the results compared to the other parameters. Finally, overall, fossil fuel consumption scores were not significantly affected by the parameters analyzed.

Figure 6.14 Sensitivity Ratios for Paper Recycling Residuals: Relative Non-BioCO2 GHGs, Differential GHGs, and Relative FF CON

6.3.2.2 *Sensitivity Analyses*

Above, perturbation analyses were applied to determine which parameters were intrinsically the most sensitive to the results without considering the actual ranges of possible values for these parameters. In Table 6.7, the results of sensitivity analyses considering the actual possible ranges of variation for each parameter are presented. It is shown that the range of possible heating values for paper recycling residuals had the most effect on the results. Also, even with the highest heating value for residuals, the GHG benefits of the biomass energy system compared to the non-use system are still considerable.

Table 6.7 Sensitivity Analyses on Indicator Results for the Typical Scenario, Paper Recycling Residuals

Para-meter	Differential GHGI* (kg CO$_2$E/GJ)			Relative Non-BioCO$_2$ GHGI* (%)			Break-Even Time* (years)			Relative FF CON (%)		
	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max
Fiber fraction		-57.8	-191		-49.6	-93.2		0	2.3		-99.9	-99.9
WC$_R$	-109‡	-108	-109	-75.2 ‡	-71.5	-75.1	0§	0	3.4	-99.9	-99.9	-99.9
FCCND		-109	-166		-75.2	-78.7		0	0		-99.9	-99.9
k		-109	-109		-75.2	-75.2		0	-0.7		-99.9	-99.9

*Computed using 100-year GWPs.†-112 kg CO$_2$E/GJ using dynamic modeling of cumulative radiative forcing.
‡-86.4% using dynamic modeling of cumulative radiative forcing.§0 years using dynamic modeling of cumulative radiative forcing.

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6.3.3   System Configuration Scenarios

In Section 5.0, various system configuration scenarios were presented. All relevant scenario combinations were analyzed (40 combinations). Results are presented in Table 6.8 for cases where parameters would be at their base case, worst, or best values. Results obtained for the typical scenarios are also reproduced in that table for comparison purposes. The biomass energy system resulted in lower GHG releases and fossil fuel consumption in almost all cases. Maximum differences were obtained in cases in which

- the fiber fraction of paper recycling residuals is higher;
- combined heat and power with maximum power production is produced;
- coal is being displaced (for both heat and power production); and
- alternative fate is landfilling.

Minimum differences were obtained in cases in which

- the plastic fraction of paper recycling residuals is higher;
- only heat is produced;
- natural gas is being displaced (for both heat and power production); and
- alternative fate is incineration.

In one specific case, slightly higher GHG releases were calculated for the biomass energy system compared to the non-use system. This effect was relatively small compared to the lower emissions observed all other cases. The higher emissions occurred under the following conditions:

- high fraction of plastic in paper recycling residuals (70%);
- heat production only;
- high water content (70%) of residuals and low boiler efficiency (54%);
- Natural gas being displaced; and
- Incineration being the alternative fate.

Table 6.8 Indicator Results for Various System Configuration Scenarios - Paper Recycling Residuals

Indicator	Unit	Typical	Min	Max
Differential GHGs*	kg CO_2E/GJ	-109†	-82.9	-316
Relative GHGs *	%	-75.2‡	-62.5%	-86.3%
Break-even time*	years	0§	0	7.6
Relative FF CON	%	-99.9	-99.9	-100

*Computed using 100-year GWPs.†- 112 kg CO_2E/GJ using dynamic modeling of cumulative radiative forcing. ‡-86.4% using dynamic modeling of cumulative radiative forcing. §0 years using dynamic modeling of cumulative radiative forcing.

6.4   Black Liquor

In a previous study by NCASI (Gaudreault et al. 2012; NCASI 2011b), the benefits of recovering black liquor for production of energy and pulping chemicals that would otherwise need to be produced from other resources were analyzed. In that study, it was determined that developing a detailed model of the alternative fate of black liquor would have required too much speculation because black liquor is not disposed. Its use in the kraft recovery cycle is integral to pulp production. Nonetheless, it was reasonable to assume that alternative management would involve returning the biogenic carbon in the liquor to the atmosphere, perhaps via incineration (in which case the carbon is emitted immediately), or aerobic wastewater treatment(in which case the carbon would be emitted

over a period of hours to months depending on the type of treatment system in use). In either case, the carbon is returned to the atmosphere far too quickly to make carbon storage a significant factor in the calculations. To be conservative, it was also assumed that all of the carbon in the black liquor would be emitted as CO_2. If, in the alternative management scenario, some of the carbon was emitted as methane, the benefits of using black liquor in the kraft recovery cycle would be larger than estimated in the study.

The detailed results obtained for black liquor can be found in NCASI (2011b) and Gaudreault et al. (2012). These are summarized in Table 6.9. At the time of this earlier study, no dynamic carbon footprint approach was applied and the results were not limited to 100 years. The break-even time would remain zero using dynamic carbon footprint but limiting the analysis to 100 years would slightly reduce the GHG benefits.

Table 6.9 Summary of Indicator Results for Black Liquor

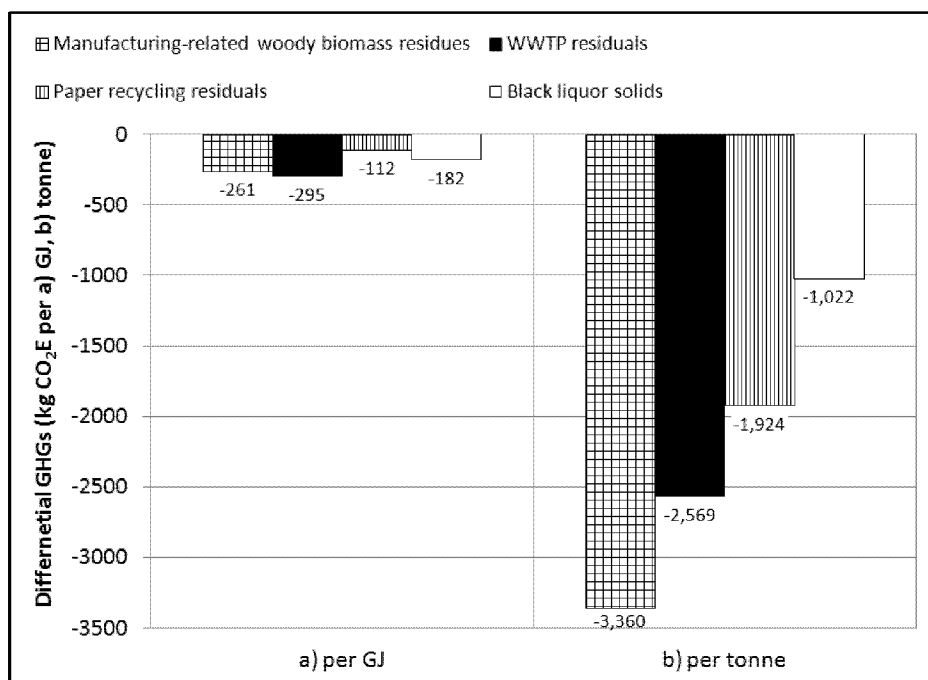| Indicator	Unit	Typical	Min	Max
Differential GHGI*	kg CO_2E/GJ	-182	-97.9	-192
Relative Non-BioCO$_2$ GHGI*	%	-90.5	-69.0	-92.4
Break-even time*·†	years	0	Not available	
Relative FF CON	%	-89.8	-71.1	-90.7

* Based on 100-year GWPs. † Break-even time was not analyzed in NCASI (2011b) and Gaudreault et al. (2012). However, assuming that the most likely alternative fate for black liquor is incineration, consistent with the conservative assumption made regarding carbon emission from this alternative fate, the break-even time would be zero years.

6.5   Comparison of the Residuals

Figure 6.15 compares the GHG benefits for the different types of biomass residuals on a) a functional unit basis (i.e., 1 GJ of energy), and b) a tonne of residual basis. "Differential GHGs" indicator results are depicted for the biomass energy system compared to the non-use system.

The figure shows that producing 1 GJ of energy using WWTP residuals produces greater benefits than does using woody mill residuals. This may seem counterintuitive, as WWTP residuals are a fuel of lesser quality than woody biomass residuals. This result was obtained because to produce 1 GJ of energy, more WWTP residuals are needed than when using woody biomass residuals, which also means diverting more WWTP residuals from landfill and hence avoiding more methane emissions. Paper recycling residuals generated relatively lower benefits than woody biomass residuals and WWTP residuals. This was due to the plastic fraction of the residuals, which produce fossil fuel GHGs when burned.

On a per tonne of residual basis, fuels with higher HHV and lower water content led to greater benefits. The plastic fraction of paper recycling residuals was also an important factor explaining the lower benefits observed for this material.

Figure 6.15 Comparison of the Differential Releases for the Different Residual Types
a) per Gigajoule, b) per Tonne

It is also possible to use the numbers presented in Table 6.13 to calculate typical scenario weighted average indicator results for all residuals included in this study. The weighted average results are presented in Table 6.10.

Table 6.10 Weighted Average Indicator Results, Typical Scenarios, Life Cycle Results

Indicator	Unit	Weighted-Average Result (all manufacturing residuals)	
		Dynamic Carbon Footprint	IPCC GWPs
Differential GHGI	kg CO_2E/GJ	-208	-206
Relative non-bioCO_2 GHGI	%	-93.3	-93.3
Break-even time	years	0	1.2
Relative FF CON	%	-93.1	-93.1

6.6   Additional Sensitivity Analysis on Air Emission Control Equipment

As mentioned in Section 5.1.2.1, it was assumed in this study that the difference in energy requirements for air emission control was negligible for boilers combusting biomass residuals, coal, and/or natural gas. There is very little information available regarding air emission control device energy requirements and where there is, it is rarely in a format that is usable for this study. Some of the available information is summarized in Table 6.11. Table 6.12 presents common air emission control equipment used for various boiler types within the forest products industry.

Based on the information in Table 6.11 and Table 6.12, two sensitivity analyses were performed to test the significance of the differences in control equipment and are summarized in Table 6.13. The results of the sensitivity analyses, presented in Figure 6.16, indicate that neglecting the differences in

energy requirements for air emission control has likely led to a slight overestimation (of less than 3%) of the benefits related to the biomass energy system, especially in the context of fossil fuel consumption benefits.

Table 6.11 Power Consumption for Various Air Emission Control Devices

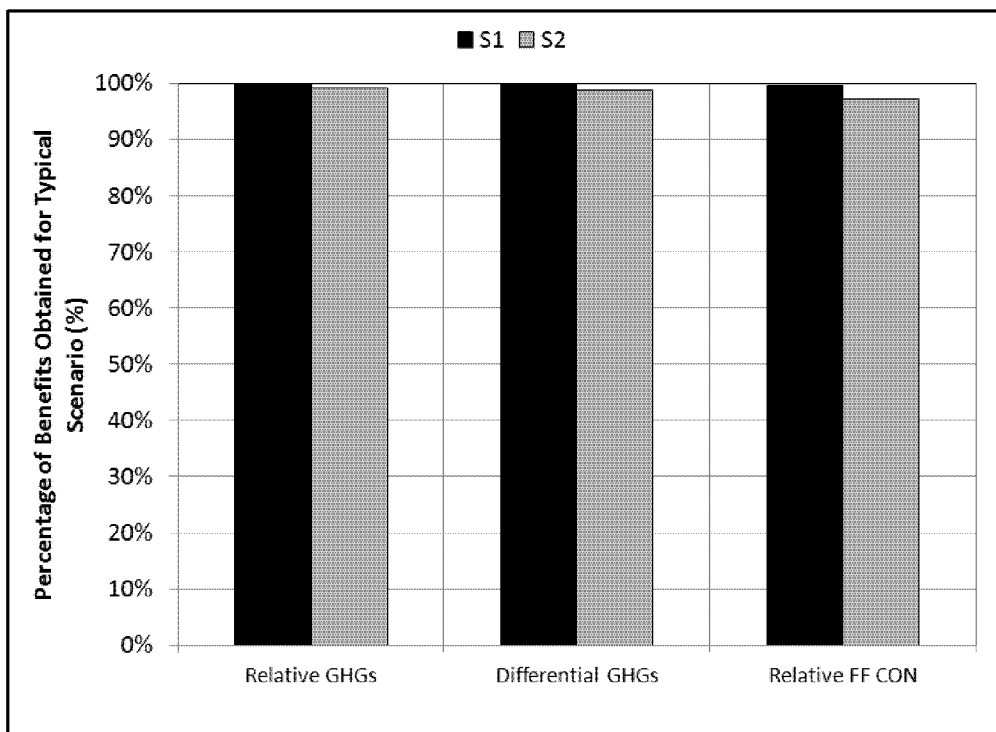| Air Emission Control Equipment	Power Consumption (% of energy output)	Applicability	Reference
Electrostatic precipitator	0.1 - 1.8%	Power utilities	European Commission (2006)
	0.2%*	Heat from coal	NCASI (1998)
	0.3%†	Heat from biomass	NCASI (1998)
	≈ 0.6%	Heat from coal‡	USEPA (2002)
Wet scrubber	≤ 3.0%	Power utilities	European Commission (2006)
Dry scrubber	0.3% - 1.0%	Power utilities	European Commission (2006)
	0.5% - 1.0%	Heat production	Kitto (1996)
Unspecified scrubber	1.0%*	Heat from coal	NCASI (1998)
	1.0%†	Heat from biomass	NCASI (1998)
Selective catalytic reduction (SCR)	0.5%	Power utilities	European Commission (2006)
Selective non-catalytic reduction (SNCR)	0.1 - 0.3%	Power utilities	European Commission (2006)

*Assuming 0.04 - 1.3 W/acfm, 0.5 acfm/(lb steam/hr) and 1.52E-03 GJ/lb steam. †Assuming 0.04 - 1.3 W/acfm, 0.92 acfm/(lb steam/hr) and 1.27E-03 GJ/lb steam.‡ Assuming 8640 hr/yr, 0.06$/kWh, 9780dscf/MMBtu, 3% O_2 at T=325°F.

Table 6.12 Common Combustion-Related Air Emission Control Equipment

Fuel Burned	Most common control equipment
Coal	ESP, low NO_x burner
Biomass	ESP, wet scrubber (newer boiler have SNCR for NO_x control)
Natural gas	Low NO_x burner, flue gas recirculation

Table 6.13 Sensitivity Analyses on Air Emission Control Equipment

#	Electricity Consumption for Air Emission Control (% of heat output)		
	Biomass	Natural Gas	Coal
S1	0.3%	0.0%	0.2%
S2	2.1%	0.0%	1.8%

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Figure 6.16 Sensitivity Analyses on Air Emission Control Equipment -
Manufacturing-Related Woody Biomass Residuals - Typical Scenario

6.7   Life Cycle Results in Context

In this study, the life cycle GHG emissions and non-renewable energy consumption associated with
the US forest products industry's use of biomass residuals (biomass energy system) have been
compared to the GHG emissions and the non-renewable energy consumption that would occur if
fossil fuels were used instead (non-use system). The results have been calculated in terms of the
differences between these two systems, expressed in terms of value chain GHG emissions. In this
section of the report, the calculated GHG benefits are put in the context of total emissions from the
forest products industry value chain in 2010.

Table 6.13 presents data that allow calculation of the greenhouse gas benefits of using biomass
residuals for energy generation. From this table, it can be seen that kraft black liquor and woody mill
residuals represent 24.3% and 34.6%, respectively, of the total energy used by the industry, for an
overall total of 58.9%.

Table 6.14 Various Contextual Data Regarding the US Forest Products Industry

Element		Value	Reference
Total energy consumption		2.58E9 GJ/yr	2010 data collected by AF&PA, NCASI, and AWC and scaled up to total US production*
Fraction of total energy from woody mill residuals (not including purchased power)		24.3%	
Fraction of total energy from black liquor generated in kraft pulping† (not including purchased power)		34.6%	
Fraction of biomass energy from various sources†	Spent liquor	66.07%	2010 data collected by AF&PA, NCASI, and AWC and scaled up to total US production*
	Woody mill residuals	29.15%	
	Forest harvest residuals	3.30%	
	WWTP residuals	0.70%	
	Paper recycling residuals	0.03%‡	
	Others	0.75%‡	
GHG benefits from black liquor recovery	Base Case	182 kg CO_2E/GJ in steam	Gaudreault et al. (2012)
	Min	98 kg CO_2E/GJ in steam	
	Max	192 kg CO_2E/GJ in steam	
Value chain emissions of the US forest products industry	Scope 1	64.6 million tonnes CO_2E/yr	Heath et al. (2010)
	Scopes 2 and 3	147 million tonnes CO_2E/yr	
	Net biogenic carbon flows	-109 million tonnes CO_2E/yr	
	Net value chain emissions	104 million tonnes CO_2E/yr	

*Together, AF&PA, NCASI, and AWC members comprise 96% of total US pulp production, 86% of total paper and paperboard production and 36% of wood products production. † Neglecting other insignificant sources of biomass energy. ‡ Estimated.

Based on these data, it is possible to estimate the increase in value chain emissions that would accompany the forest products industry's changing from woody mill residuals to fossil fuels. This calculation indicates that burning these residuals for energy in the forest products industry for one year avoids 110 million tonnes CO_2E[18] (ranging from 32.9 to 192 million tonnes CO_2E). A comparable analysis for black liquor was previously undertaken and published, with the conclusion that the use of black liquor in the kraft recovery system avoids the release of 182 kg CO_2/GJ (ranging from 98 to 192 kg CO_2E/GJ) (Gaudreault et al. 2012). Using the same data set as for woody mill residuals (2010 data), the current study indicates that the industry's use of black liquor in the kraft recovery system for one year avoids 109 million tonnes CO_2E (ranging from 59.0 to 115 million

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[18] All values calculated in this section of the report include the difference in releases of biogenic CO_2. In the case of the Heath et al. (2010), only the net flow of biogenic was shown, as only the net was calculated.

tonnes CO_2E) attributable to the use of black liquor in the kraft recovery system. Overall, therefore, the use of biomass-based manufacturing residuals in the forest products industry for one year avoids, for typical scenarios, the emissions of 218 million tonnes CO_2E (ranging from 91.5 to 307 million tonnes CO_2E). In an earlier study, it was determined that direct emissions of GHGs from fossil fuel combustion in the US forest products industry in 2004 were approximately 60 million tonnes CO_2E per year (Heath et al. 2010). The use of biomass-based manufacturing residuals for one year, therefore, avoids a quantity of GHG emissions more than three times the annual fossil-fuel related direct GHG emissions from the forest products industry.

7.0   RESULTS AND DISCUSSION: ADDITIONAL ANALYSES

This section presents the results of the gate-to-gate analysis of biogenic GHGs and the analysis of the emissions of GHGs in the context of ongoing practices.

7.1   Gate-to-Gate Analysis of Biogenic GHGs

All the results presented above were computed using a life cycle approach that considered the fossil fuels being displaced by biomass residuals. The typical scenarios for the two product systems (i.e., one system using biomass for energy and the other system managing it by some other means) have also been compared in terms of the emissions coming directly out of the units receiving the residuals (i.e., combustion units or landfills). In this analysis, the benefits of fossil fuel substitution were ignored. For the gate-to-gate analysis, paper recycling residuals were analyzed in terms of their fiber fraction only.

Gate-to-gate Differential GHGI results are summarized in Table 7.1. These show that, even in this highly constrained analysis, using the biomass residuals for energy generation resulted in significant GHG release reductions. A significant fraction of the emissions benefits were attributable to avoidance of landfill methane. A previous, similarly constrained analysis on black liquor assumed that the alternative management would almost certainly involve returning the biogenic carbon in the liquor to the atmosphere. In order to be conservative, in that study, it was assumed that the carbon would return to the atmosphere as CO_2 via incineration or treatment in aerobic wastewater treatment plants. This resulted in net zero GHG releases for energy production compared to an alternative fate. When not considering fossil fuel substitution, the weighted average improvement in GHG emissions associated with the use of all manufacturing residuals, including black liquor, was shown to be approximately 50 kg CO_2E/GJ.

Because the benefits of displacing fossil fuels are not included, the times required for cumulative emissions from the biomass energy system to fall below the cumulative emissions from the non-use system are longer than calculated earlier in this report. Depending on the residual, it required 0 to 7.7 years, with a weighted average of 2.4 years for typical scenarios (including black liquor), for the cumulative emissions from the biomass system to become lower than the cumulative emissions from the non-use system.

Table 7.1 Results of the Gate-to-Gate Analysis of Biogenic GHGs

Residual Type	Differential GHGs over 100 Years (kg CO$_2$E/GJ)		Break-Even Time (years)	
	Dynamic CF	IPCC 100-Year GWPs	Dynamic CF	IPCC 100-Year GWPs
Woody mill residuals	-154	-147	7.4	17.3
WWTP residuals	-190	-182	5.9	13.4
Fiber fraction of paper recycling residuals*	-132	-126	7.7	18.2
Black liquor	0	0	0	0
Weighted average of biomass manufacturing residuals	-51.1	-48.96	2.4	5.7

* In addition to biomass, paper recycling residuals contain plastics which are produced from fossil fuels. For the purpose of the biomass carbon fate analysis, only their fiber fraction was considered.

7.2   GHG Emissions from Ongoing Use of Residuals for Energy Production

Table 7.2 shows the times required for annual and cumulative emissions from a facility using residuals for energy to be equal to the emissions from a facility disposing of the residuals, both for the cradle-to-energy (including fossil fuel substitution) and gate-to-gate (excluding fossil fuel substitution) analyses. The results are presented for the dynamic carbon footprint approach only. The table also indicates when in the past the ongoing practice would have had to begin in order for the emissions from the two systems to be equal in 2014. The table includes text describing the practices in the industry at points in the past. It should be noted that there is considerable uncertainty in the estimates of break-even times, especially where fossil fuel substitution is ignored. This is because, in cases where fossil fuel substitution benefits are ignored, the curve describing the difference in cumulative emissions between the two scenarios is relatively flat as it approaches zero (because the initial difference between the scenarios is large). The break-even time is equal to the point at which the curve passes through zero, so the results are sensitive to small changes in assumptions, particularly assumptions about landfill decay and methane production. By contrast, where fossil fuel substitution is considered, the curve is steeper where it passes through zero because of the smaller initial difference between the two scenarios, thus reducing the uncertainty about break-even time.

Table 7.2 The Use of Residuals for Energy as an Ongoing Practice

Residual		Years For Emissions from Facility Using Residuals for Energy on an Ongoing Basis to Be Equal to Emissions from a Facility Disposing of These Residuals (Under Typical Scenario)		Year in the Past When Ongoing Practice Would Have Had to Be Initiated for Emissions from the Two Facilities to Be Equal in 2014 (Under Typical Scenario)		Past Industry Practice in Using the Residuals for Energy
		Annual Emissions	Cumulative Emissions	Annual Emissions	Cumulative Emissions	
Woody mill residuals	w/ benefits of the displaced fossil fuels (cradle-to-energy)	0.6	1.3	2013	2012	Based on AF&PA statistics, in 1971, woody mill residual represented 7% of the fuel (16% of the biomass) burned at pulp and paper mills. By 1980, this had increased to 11% of the fuel (21% of the biomass). Between 1987 and 1999, it varied between 15% and 18% of the fuel (25% to 29% of the biomass). Statistics for wood products mills are less robust, but woody fuels have been commonly used for lumber drying, and before that, steam engines, since these technologies were first introduced. The literature mentions the use of wood residuals in boilers used for wood drying at sawmills going back to at least 1920 and in steam engines in sawmills going back to the mid-1800s.
	w/o benefits of the displaced fossil fuels (gate-to-gate)	7.4	16.2	2007	1998	
WWTP residuals	w/ benefits of the displaced fossil fuels (cradle-to-energy)	0	0	2014	2014	NCASI statistics on WWTP residuals management go back to 1979, at which point 11% of these residuals was being burned for energy. By 1988, this had increased to 21%.
	w/o benefits of the displaced fossil fuels (gate-to-gate)	5.9	12.6	2008	2001	

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Residual	Years For Emissions from Facility Using Residuals for Energy on an Ongoing Basis to Be Equal to Emissions from a Facility Disposing of These Residuals (Under Typical Scenario)		Year in the Past When Ongoing Practice Would Have Had to Be Initiated for Emissions from the Two Facilities to Be Equal in 2014 (Under Typical Scenario)		Past Industry Practice in Using the Residuals for Energy
	Annual Emissions	Cumulative Emissions	Annual Emissions	Cumulative Emissions	
Paper recycling residuals — w/ benefits of the displaced fossil fuels (cradle-to-energy)	0	0	2014	2014	There are different types of recycling residuals generated by mills using recovered paper. Some of these are combined with WWTP residuals and managed similarly to what is described above; i.e., in 1979 11% of WWTP residuals were burned for energy, increasing to 21% in 1988. OCC rejects, however, are often managed separately. NCASI has published information showing that using recycling residuals for energy started as early as 1975.
Paper recycling residuals — w/o benefits of the displaced fossil fuels (gate-to-gate)	7.7	16.8	2006	1997	
Black liquor — w/ benefits of the displaced fossil fuels (cradle-to-energy)	0	0	2014	2014	Based on AF&PA statistics, in 1971, 35% of the fuel (84% of the biomass) burned at pulp and paper mills was black liquor. By 1980, this had increased to 40% of the fuel (79% of the biomass). Between 1987 and 1999, it varied between 43% and 46% of the fuel (71% to 75% of the biomass).
Black liquor — w/o benefits of the displaced fossil fuels (gate-to-gate)	0	0	2014	2014	
Weighted average of biomass mfg. residuals — w/ the benefits of the displaced fossil fuels (cradle-to-energy)	0.2	0.4	2013	2013	N/A
Weighted average of biomass mfg. residuals — w/o the benefits of the displaced fossil fuels (gate-to-gate)	2.4	5.5	2012	2008	

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8.0   UNCERTAINTY AND LIMITATIONS

This section provides further interpretation of the robustness of the results presented above.

8.1   Data Accuracy and Uncertainty

Evaluating data accuracy and uncertainty is an important aspect of LCA studies. An LCA is a complex model made up of thousands of data points and the accuracy of these data can highly affect the results. Analyzing the uncertainty of such a complex model is not straightforward. Techniques such as Monte Carlo analysis can be used to evaluate uncertainty, but an important challenge is the lack of uncertainty data for the different variables that comprise the LCA model. Therefore, in many cases, the robustness of the results and conclusions of LCA studies are assessed using other methods. In this study, the parameters with potential effects on the results were analyzed using sensitivity analyses covering their most probable range of variation and results were discussed given these variations. However, without comprehensive uncertainty data, it was impossible to quantitatively assess the statistical significance of the differences between the compared systems.

The data collection process met the data quality goals as set out in Section 4.4.

8.2   Limitations

The main limitations of this study are summarized in this section. They relate primarily to the conformity of the study with ISO LCA standards (ISO 2006a, b) and to the data used and assumptions made.

8.2.1   ISO Conformity

As mentioned previously, a streamlined LCA methodology was used in this study. As a consequence, it was not possible to fully comply with ISO 14044 requirements for comparative assertions disclosed publicly. The main non-conformances are outlined below.

- Although the assumptions, models and results were reviewed by a committee of stakeholders, no formal external critical review was performed.
- While the Standard requires that for studies intended to be used for publicly disclosed comparative assertions, a sufficiently comprehensive set of impact categories be employed, only two were used in this study, in accordance with the study objective.
- No formal uncertainty analysis was performed.

In addition, the gate-to-gate analyses need to be understood as additional information rather than as an LCA result.

8.2.2   Data and Assumptions

Some of the generic data sets used in this study were not specific to the US, although the study employed a version of these data sets modified to use US electricity production.

The relevant characteristics related to the residuals analyzed in this study are typically quite variable. This variability was analyzed in sensitivity analyses and results were shown for range of characteristic values sufficiently large to cover most of the variability.

The data identified for size reduction were fixed on a per tonne basis and did not account for the extent of size reduction. That said, size reduction was not found to significantly affect the study results.

Several assumptions were made regarding WWTP residuals that could have affected the study results. The main ones are discussed here.

- It was assumed that mechanical dewatering can achieve 40% solids, that this was sufficient for combustion, and that the same level of dewatering was also suitable for transporting them to a landfill disposal site. The main reason for this assumption was that no data were available concerning the energy consumption for additional dewatering. Assuming additional dewatering would have had two main effects on the results. First, this would have decreased the overall performance of the biomass energy system by increasing its consumption of energy and related releases. Second, assuming drier WWTP residuals would have increased boiler efficiency, and thus reduced the quantity of residuals required to produce 1 GJ of energy, which would have resulted in lower benefits when analyzing the results on a per gigajoule basis, but greater benefits on a per tonne of residuals basis.

- It was also assumed that WWTP residuals would be co-fired with bark in a 20:80 ratio. Based on this ratio, a boiler efficiency was calculated. Increasing the share of residuals in the mix burned would have decreased the boiler efficiency, while decreasing their share would have increased the efficiency. The effect of boiler efficiency on the results was discussed immediately above. The relationship between the share of WWTP residuals burned and boiler efficiency is also uncertain. The best available information was used.

Because paper recycling residuals are made up of a mix of a materials that have characteristics similar to WWTP residuals (negative effect on boiler efficiency compared to woody biomass residuals) and plastic (positive effect on boiler efficiency compared to woody biomass residuals), it was assumed that paper recycling residuals would be burned in boilers with the same efficiency as woody biomass residuals at a given water content. Boiler efficiencies for these kinds of material are not known, however. The effect of boiler efficiency on the results was discussed above. Also, OCC rejects were considered to be representative of paper recycling residuals in general. In cases where, for instance, the plastic fraction of other paper recycling residuals is outside the range studied in this study, results would be slightly different. However, a broad range of characteristics were examined in this study to account for that eventuality.

The best available data for energy production using fossil fuels were used. These data were deemed representative of average US conditions. No sensitivity analyses were performed on that part of the modeling. As a consequence, the results of the study cannot be generalized to a broader set of conditions regarding energy production from fossil fuels. Also, it was assumed that the difference in energy requirements for air emissions control would not vary significantly from one fuel to another. If this were not the case, and in particular if the energy penalty for emissions control were lower for natural gas than for biomass, the benefits calculated for scenarios involving natural gas would be reduced. This is not, however, expected to be significant.

The results are very sensitive to landfill and waste decomposition characteristics and these characteristics are very uncertain. Sensitivity analyses were performed to address this issue. Results appear to be robust within the ranges assessed for those characteristics. The analysis of the timing of emissions depends heavily on those landfill characteristics. In the absence of information more specific to forest products manufacturing residuals, USEPA decay rates for municipal landfills were used. These decay rates were derived for a mix of wastes, i.e., not only for woody materials which may degrade more slowly. Therefore, the lower decay rates used in the scenarios are probably more representative of woody materials. Even considering this, the break-even times were short, with the exception of paper recycling residuals that contain a fraction of plastic.

Finally, the results on the ongoing practice analyzes are valid only in the context of two main assumptions: 1) assuming the same quantity and type of energy produced in every years, 2) assuming the same alternative fates and fossil fuel displaced in every year.

9.0   CONCLUSIONS

In this study, the GHG and fossil fuel-related benefits of using woody manufacturing residuals, recycling residuals, and wastewater treatment plant residuals for energy production within the forest products industry were analyzed using life cycle principles and other additional analyses. It was shown that using all types of residuals for energy production produces significant benefits both in terms of reduced fossil fuel consumption and reduced greenhouse gas emissions. This result is valid across a range of system configuration scenarios (boiler type, assumptions about the displaced fossil fuel, the GHG intensity of the electricity grid, and the level of cogeneration at forest products facilities), residual characteristics (e.g., heating value, moisture content), and whether or not the benefits from fossil fuel substitution are considered. These findings hold true whether biogenic CO_2 is included in the analysis or excluded by giving it an emission factor of zero (equivalent to what is sometimes called "carbon neutrality"). The benefits occur without affecting the amount of wood harvested or the amount of wood products produced. It typically takes less than one year before the cumulative emissions in the biomass energy system are lower than those in the corresponding non-use system, with a weighted average (reflecting industry's typical usage rate) of about one year. Even ignoring the benefits of displacing fossil fuel and limiting the analysis to biogenic emissions, the cumulative emissions from the biomass energy systems associated with producing 1 GJ of energy are lower than those from the non-use systems in 0 to 7.7 years, depending on the residual, with a weighted average of 2.4 years.

When considered as an ongoing practice (e.g., ongoing production of 1 GJ energy per year), and when the benefits of displaced fossil fuels are considered, the cumulative impact associated with the typical mix of residuals used for energy in the industry becomes less than that of disposing of the residuals in less than one year. If the benefits of displaced fossil fuels are ignored, the cumulative impact associated with using the typical mix of residuals becomes smaller than the impact associated with disposing of the residuals in less than six years.

The emissions benefits of using manufacturing residuals for energy in the forest products industry are large. Given current practice, the use of manufacturing residuals (including black liquor) in the industry for one year avoids the emission of approximately 218 million tonnes CO_2E, equal to more than three times the annual direct emissions associated with the combustion of fossil fuels in the forest products industry.

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APPENDIX A

ACRONYMS AND NOMENCLATURE

General Acronyms and Nomenclature:

AF&PA: American Forest and Paper Association

AWC: American Wood Council

BC: Base case

BDmT: Bone-dry metric tonne

Bio: Biomass

BioCO$_2$: Biogenic CO$_2$

Biogenic GHGs: Biogenic CO$_2$ as well as CH$_4$ produced from decomposing biomass and CH$_4$ and N$_2$O produced in biomass combustion

Biomass energy system: Product system in which the biomass residuals are used for energy production

Break-even time: Number of years required for the cumulative emissions from the non-use system to equal the cumulative emissions from the biomass energy system

CHP: Combined heat and power

CORRIM: Consortium for Research on Renewable Industrial Materials

CO$_2$: Carbon dioxide

CO$_2$E: CO$_2$ equivalents, i.e., measure for describing how much global warming a given type and amount of greenhouse gas may cause, using the functionally equivalent amount or concentration of carbon dioxide (CO$_2$) as the reference

Cradle-to-final energy analysis: A cradle-to-final energy analysis can be defined as a specific LCA applied to the production of energy. It generally includes the extraction and production of fuels, their transportation and their combustion to produce energy.

Differential GHGs: Absolute difference in releases of GHGs, including biogenic CO$_2$ emissions and removals

Eff: Efficiency

EPA: Environmental Protection Agency

FF: Fossil fuel

Non-use system:	Product system in which the fossil fuels are used for energy production and in which an alternative fate for the biomass residuals is considered or in which only the alternative fate of the biomass residuals is considered
Gate-to-gate analysis:	A gate-to-gate analysis can be described as a partial LCA looking at only one value-added process in the entire production chain
GHG:	Greenhouse gas
GJ:	Gigajoule (1 GJ = 0.948 MMBtu)
GWP:	Global warming potential
HHV:	Higher heating value
H&P:	Heat and power
ISO:	International Organization for Standardization
LCA:	Life cycle assessment
LCI:	Life cycle inventory
LCIA:	Life cycle impact assessment
LHV:	Lower heating value
NG:	Natural gas
N/Av.:	Not available
OCC:	Old corrugated containers
OECD:	Organisation for Economic Co-operation and Development
Relative FF CON:	Relative difference in fossil fuel consumption of the biomass energy system compared to the non-use system
Relative Non-Bio CO_2 GHGs:	Relative difference in GHGs, not including biogenic CO_2, of the biomass energy system compared to the non-use system
Removals:	Sequestration or absorption of CO_2 from the atmosphere by the trees
US:	United States
WWTP:	Wastewater treatment plant

System Configuration Scenarios Nomenclature:

Alternative Fate Scenarios

MR1:   Landfilling

MR2:   Incineration

Boiler Type Scenarios

FB: Fluidized bed boiler

SB: Stoker boiler

Fossil Fuel Scenarios

A: Heat from coal

B: Heat from natural gas

C: US-average electricity

D: Electricity from coal

E: Fossil fuel scenario, electricity from natural gas combined cycle

Size Reduction Scenarios

SR0:   Size reduction scenario, no size reduction

SR1:   Size reduction scenario, mobile chipper

SR2:   Size reduction scenario, stationary chipper

General Nomenclature:

CC: Biogenic carbon content

E_{DC}: Usable energy from direct combustion

E_{Turb}: Steam to turbine

F_{CCND}: Non-degradable carbon content under anaerobic conditions

F_{CH4CB}: Fraction of methane captured and burned

F_{CH4OX}: Fraction of methane oxidized in landfill covers

k: Decay rate

L: Losses

MCF: Methane correction factor

P: Power to process

Q_R: Quantity of residuals required to produced 1 GJ of usable energy

SHP: High pressure steam to process

SMP/LP: Extraction steam to process

WC_R: Water content of residuals

Grouping Montana and Idaho with surrounding states for biogenic accounting

National Council for Air and Stream Improvement [*]

May 8, 2014

Background

EPA plans to release a new version of its accounting framework for biogenic CO_2 emissions from stationary sources during the first half of 2014. It is expected that the new framework will include a procedure for calculating Biogenic Accounting Factors (BAFs) that is based, in part, on forest conditions in regions of the United States.

Regions should consist of states that are related ecologically and where similar levels of forest management are taking place. For example, the following 4 regions result in reasonable state groupings for analysis purposes (Fig 1):

- North: CT, DL, IL, IN, IA, KS, MA, ME, MD, MI, MN, MO, NE, NH, NJ, NY, ND, OH, PA, RI, SD, VT, WV, WI

- South: AL, AR, FL, GA, KY, LA, NC, OK, SC, MS, TN, TX, VA

- SouthWest: AZ, CO, NV, NM, UT

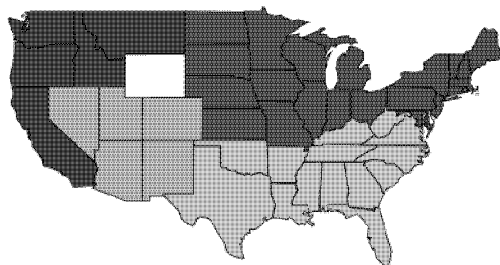- PacifCoastNW: CA, OR, WA, ID, MT

---

[*]http://www.ncasi.org/

Figure 1: Analysis regions

FIA does not yet have sufficient annual inventory data (Anonymous , 2012) for WY for that state to be included in the analysis. FIA data for AK are generally limited to coastal areas and were not included. MT and ID are grouped with the Pacific Coast states, because they have similar levels of industrial forest activity and share ecological characteristics (Fig 2). We support this grouping with data from the FIA timber products output (TPO) survey and Bailey's (Bailey , 1983) ecological provinces.

Grouping Strategy

We propose grouping states into four regions (Figure 1). The North and South regions closely correspond to FIA regions. The other two regions differ from FIA regions in that we have assigned Montana and Idaho to the Pacific Coast NW region rather than the South West. We have proposed this grouping because Montana and Idaho both have significant forestry taking place unlike the South West. Furthermore, our analysis shows the South West is the only region with recent per acre mean above ground biomass (AGB) decline which is likely due to drought, insects, diseases, and fire rather than forest harvesting. Placing Montana and Idaho in the South West region would tend to diminish and obscure the South West AGB decline.
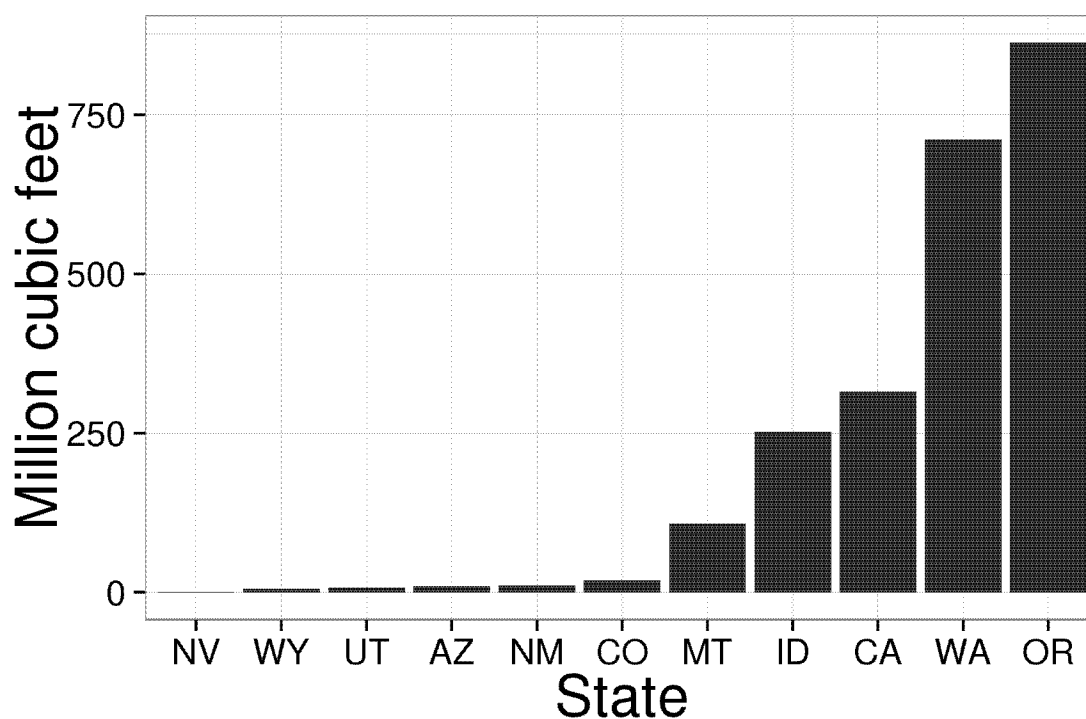
Figure 2: FIA Timber Product Output removals data (excluding firewood)

Support for grouping ID and MT with the Pacific Coast states

Harvest removals data from the FIA TPO database suggest (Fig 2) that ID and MT fit better with CA, OR and WA than with the SouthWest states. Removals from ID and MT are at levels more similar to CA, OR, and WA than to the SouthWest states.

Bailey's eco-provinces also lend some support for grouping ID and MT with the Pacific Coast states. In particular, ID and MT are similar ecologically to western WA and OR (Fig 3). FIA forested plots are colored according to Bailey's province (Fig 3), which shows more province overlap with OR and WA than with neighboring SouthWest states.

The timberland acreage by Bailey's province and state (Tab 1) allows for closer scrutiny of the relationship between MT, ID and surrounding states. Most of the timberland acreage in MT and ID is in Bailey provinces M332 "Middle Rocky Mountain Steppe–Coniferous Forest–Alpine Meadow Province" and M333 "Northern Rocky Mountain Forest-Steppe–Coniferous
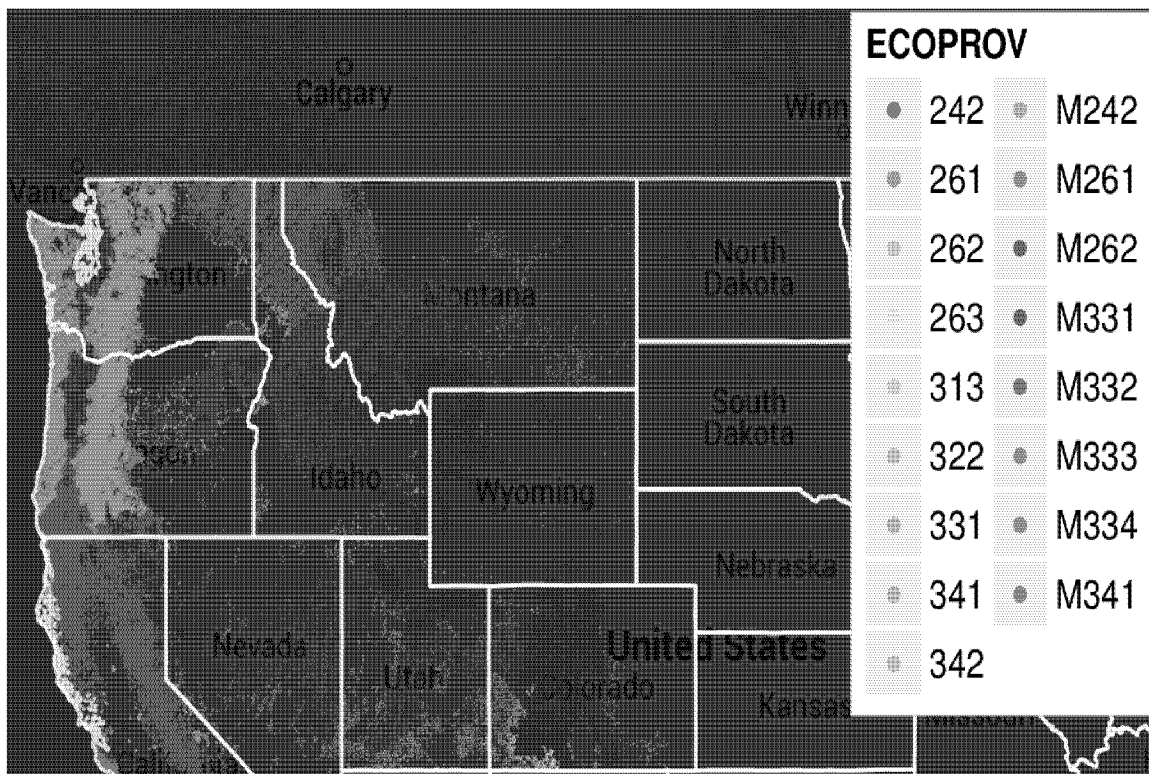
Figure 3: FIA plots colored by Baileys eco-province.

Forest–Alpine Meadow Province". Table (1) indicates that provinces M332 and M333 also have significant acreage in OR and WA. ID and MT also have some timberland acreage in province 331 "Great Plains-Palouse Dry Steppe Province" which is shared with OR and WA, but also with CO and WY. There is also some acreage in M331 "Southern Rocky Mountain Steppe–OpenWoodland–Coniferous Forest–Alpine Meadow Province" that is not shared with OR or WA. Regardless, ID and MT have more timberland acreage in provinces that are found in WA and OR than with any other states.

A map of AGB also supports grouping ID and MT with CA, OR and WA. The greener areas (Fig 4) indicate more per acre AGB. Generally, MT and ID have higher levels of per acre AGB than the other SouthWest states. CO may be an exception and WY has too little FIA annual inventory data available yet to make a definitive statement.

Prov	CA	CO	ID	MT	NV	OR	UT	WA	WY	All
242						616		1540		2156
261	237									237
262	7									7
263	2104					29				2134
313		513					37			551
322					7					7
331		226	559	2275		5		55	414	3534
341	163	320			45		214			742
342	6	12	611		53	314	28	317	216	1556
M242						15358		13041		28399
M261	14323				90	3355				17769
M262	221									221
M331		9644	1486	1264			1819		4342	18555
M332			8304	8668		5776		321		23069
M333			5936	7403				3935		17274
M334									447	447
All	17061	10858	16896	19609	295	25454	3767	19209	5419	118566

Table 1: Timberland acres (x1000) by state and Bailey's province.
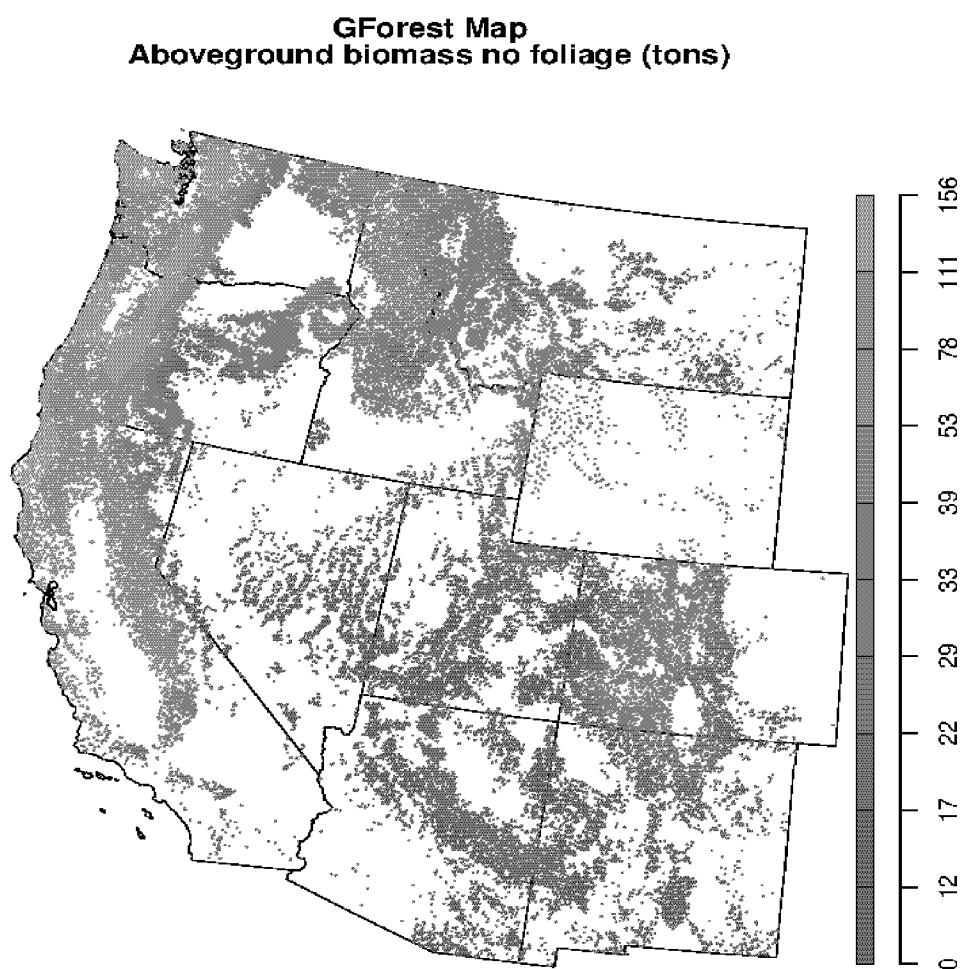
Figure 4: FIA plot locations colored according to above ground biomass. A loess smoothing procedure is applied to enhance AGB spatial patterns.

Conclusions

The lower 48 states could be grouped by a number of criterion for biogenic accounting purposes. We chose to keep most of the states within their FIA designated regions. Our southern region is the same as FIA's southern region, and our northern region is nearly the same. However, we created a PacificCoastNW and a SouthWest region that differ somewhat from FIA regions. In particular, we grouped MT and ID with CA, OR and WA, because they have similar levels of industrial forest activity and share many ecological characteristics. Also, the SouthWest region shows recent AGB declines that are likely due to fires, insects and diseases rather than harvesting. Therefore, it seems reasonable to separate the SouthWest region to facilitate further analysis.

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From:	Ohrel, Sara
To:	Cole, Jefferson
Sent:	6/11/2014 3:46:30 PM
Subject:	for our discussion
Attachments:	Task list June 11.docx

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
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Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Sara Bushey Ohrel
Sent:	6/9/2014 1:46:21 PM
Subject:	Fw: FYI - deliberative
Attachments:	Framework_Report_5 1_Final_ogc otaq oaqps af TB bi_5 30 14.docx

Sent from my BlackBerry 10 smartphone.

From: Ohrel, Sara
Sent: Friday, May 30, 2014 3:00 PM
To: Cole, Jefferson; Justin Baker (justinbaker@rti.org); Robert H. Beach (rbeach@rti.org); Greg Latta
Subject: FYI - deliberative

Hi crew,
Just so you all have it – here is the draft main doc with comments from Allen, Bill, OTAQ, OAQPS, OGC, and Thomas Buchholz. I will add in Steve P's when we get them.

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

Sent from my BlackBerry 10 smartphone.

From: Baker, Justin
Sent: Tuesday, June 3, 2014 8:33 AM
To: Ohrel, Sara; Cole, Jefferson
Subject: FW: Review of Draft

This email and all attachments are deliberative

Hi Sara,

Please find comments from Steve P on the AF2 Framework document. If you prefer, I can merge these with the current version that has merged EPA comments.

Thanks,
Justin

-----Original Message-----
From: Prisley, Stephen [mailto:prisley@vt.edu]
Sent: Monday, June 02, 2014 11:01 PM
To: Baker, Justin
Subject: Review of Draft

Justin-

Attached is my review of the 5_1 version of the framework main report; comments are noted in track changes mode.

In general, the writing is clear and concise and in very good shape. My comments are very minor and mostly typographical.

Ex. 5 - Deliberative

Steve

From:	Ohrel, Sara
To:	Cole, Jefferson
Sent:	5/30/2014 2:37:24 PM
Subject:	RE: data evaluation plan -revised- *Deliberative*
Attachments:	App D Feedstock Categories 4 26 14_comments so.docx; Appendix E Leakage_042514_withedits.docx; Appendix F 4 25 14 clean with comments.docx; Appendix G so.docx; Appendix K_Anticipated Baselines Background 4 28so.docx; Appendix_B_Temporal Scale 4 29 2014-psg2so.docx; Appendix_C_Spatial Scale-psg_SMB_4-27so.docx; DRAFT App H_RP Landscape Atts_4 25_clean w comments_ICF so_C.docx; DRAFT App I_Ref Pt Case Studies_4 28 2014so.docx; DRAFT App L FABA Case Study App 4 29 2014_v2.docx; DRAFT App M Both baselines CS Results 3 12 14_vF_so_gl 4 26 so_gl.docx; DRAFT FABA Baseline Constrn 4 27 2014 so.docx

In some apps, some comments have been addressed so you will have to look through and pick out the ones that still need to be addressed – in most cases, we state 'to address next round" or something similar:

A. We will use your recent version
B. 4/29
C. 4/27
D. 4/26
E. 4/25
F. 4/25
G. G so (4/30)
H. 4/25
I. 4/28
J. 4/28 (says app k)
K. 4/27 baseline
L. 4/29
M. 4/26
N. You should have that

From: Cole, Jefferson
Sent: Friday, May 30, 2014 12:00 PM
To: Ohrel, Sara
Subject: RE: data evaluation plan -revised- *Deliberative*

I think that would be best, even if it means copying them into comment bubbles of my own and saying who they are from and when. Still a headache, but it will make for something cleaner without accidentally reverting back to old text.

So yes, go ahead and send me the old appendix files (w/ comments, pre-May 1) to make sure we're on the same page as far as that goes, and I'll see what I can do.

From: Ohrel, Sara
Sent: Friday, May 30, 2014 11:57 AM
To: Cole, Jefferson
Subject: RE: data evaluation plan -revised- *Deliberative*

However you would like to get the old comments (eg we need to do this, revisit that) into the clean docs is fine with me J

From: Cole, Jefferson
Sent: Friday, May 30, 2014 11:56 AM
To: Ohrel, Sara
Subject: RE: data evaluation plan -revised- *Deliberative*

That may be complicated/confusing to pull off. At least in terms of merging.

The reason the merging of the other docs on top of the clean version work is because they were all done off of the same clean doc. Merging any of these with an old doc will also mark any edits done between the commented versions of the apps, and their may 1 version, will show up as an edit done by the person who edited the new file to be merged in.

If anything, I think we should bring over comments from the old version (not text edits) to a newer clean version with the new comments.

What do you think?

Jeff

From: Ohrel, Sara
Sent: Friday, May 30, 2014 11:50 AM
To: Cole, Jefferson
Subject: RE: data evaluation plan -revised- *Deliberative*

One more thing – please merge them into our commented versions of the apps, not the clean versions. I can send you the latest.

From: Cole, Jefferson
Sent: Friday, May 30, 2014 11:13 AM
To: Ohrel, Sara; Baker, Justin
Subject: RE: data evaluation plan -revised- *Deliberative*

I think that is an excellent plan, Sara. I'm glad you two talked.

I'll continue collating comments. In the meantime Justin, I will respond to any questions you have regarding the data analysis. Feel free to call me if you think that is easier. I'll be at my desk most of the day except from 12.30 to 1.30.

Thanks,

Jeff

From: Ohrel, Sara
Sent: Friday, May 30, 2014 11:11 AM
To: Baker, Justin; Cole, Jefferson
Subject: RE: data evaluation plan -revised- *Deliberative*

Hi all,
Justin and I just chatted – as RTI is busy with OTAQ comparison and L&P, they will hold off working on the main document, and I will consolidate the current version from Jeff (thanks!) with comments we just got from Thomas B. Jeff, can you please work on consolidating comments received on appendices thus far if you aren't already (I know you have already done App A).
Thanks!
Sara

From: Baker, Justin [mailto:justinbaker@rti.org]
Sent: Friday, May 30, 2014 9:54 AM
To: Ohrel, Sara; Cole, Jefferson
Subject: RE: data evaluation plan -revised- *Deliberative*

We're taking a look at all comments, but have not started drafting anything yet.

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Friday, May 30, 2014 9:53 AM
To: Baker, Justin; Cole, Jefferson
Subject: RE: data evaluation plan -revised- *Deliberative*

Hi Justin,
Do you mean for all comments or specific ones like Ex. 5 - Deliberative ?

From: Baker, Justin [mailto:justinbaker@rti.org]
Sent: Friday, May 30, 2014 9:52 AM
To: Cole, Jefferson
Cc: Ohrel, Sara
Subject: RE: data evaluation plan -revised- *Deliberative*

Also, we're currently reviewing OAQPS comments on the AF2 document to start drafting responses and/or edits to the document. Do you have edits/comments from OTAQ, OGC, or others that you would also like us to look at?

From: Cole, Jefferson [mailto:Cole.Jefferson@epa.gov]
Sent: Friday, May 30, 2014 9:47 AM
To: Baker, Justin
Cc: Ohrel, Sara
Subject: RE: data evaluation plan -revised- *Deliberative*

Excellent. Thanks, Justin.

Jeff

From: Baker, Justin [mailto:justinbaker@rti.org]
Sent: Friday, May 30, 2014 9:43 AM
To: Cole, Jefferson
Cc: Ohrel, Sara
Subject: RE: data evaluation plan -revised- *Deliberative*

Thanks, Jeff.

We're plugging away at this. We'll have plenty to discuss next week.

Justin

From: Cole, Jefferson [mailto:Cole.Jefferson@epa.gov]
Sent: Thursday, May 29, 2014 5:43 PM
To: Baker, Justin
Cc: Ohrel, Sara
Subject: data evaluation plan -revised- *Deliberative*

This email is Deliberative

Hello Justin,

Thanks again for all the work on the data comparison. I've attached a slightly revised version of the document I sent

you yesterday following our phone call, adding lines for

Ex. 5 - Deliberative

Thanks, and let me know if you have any questions.

Best,

Jeff

_____

Jefferson Cole
Economist
Climate Change Division
U.S. EPA
202.343.9671
cole.jefferson@epa.gov

From:	Cole, Jefferson
To:	Ohrel, Sara
Sent:	5/29/2014 6:52:11 PM
Subject:	compiled main doc comments *Deliberative*
Attachments:	Framework_Report_5 1_Final + ogc otaq oaqps af comments 5-29-14.docx

This email is Deliberative

Sara,

I've attached the main document with all comments received so far from OGC, OTAQ, OAQPS, and Allen. All of OAQPS's comments and suggested edits were entered as comments, labeled as "OAQPS: ...". This also includes the two suggested paragraphs they sent earlier today.

Finally, I was able to transcribe all of Allen's comments/edits and entered them with accompanying comments (e.g., "edits from Allen").

Jeff

_____

Jefferson Cole
Economist
Climate Change Division
U.S. EPA
202.343.9671
cole.jefferson@epa.gov

From:	Cole, Jefferson
To:	Ohrel, Sara
Sent:	5/29/2014 10:58:52 AM
Subject:	RE: Weekly Team Biomass meeting
Attachments:	Framework_Report_5 1_Final + ogc otaq comments 5-29-14.docx

Here's the main doc with combined comments from ogc and otaq

Jeff

From: Ohrel, Sara
Sent: Thursday, May 29, 2014 10:46 AM
To: Cole, Jefferson
Subject: RE: Weekly Team Biomass meeting

Ok, please send me what you have for our chat. thanks!

From: Cole, Jefferson
Sent: Thursday, May 29, 2014 10:35 AM
To: Ohrel, Sara
Subject: RE: Weekly Team Biomass meeting

Sara,

I am still working on collating the main doc comments.

In the meantime, here is the collated Appendix A comments.

Jeff

<< File: Appendix_A_IPCC_Emissions Inventory_5 1_Final Comments OGC OAQPS.docx >>

From: Ohrel, Sara
Sent: Thursday, May 29, 2014 10:31 AM
To: Irving, Bill; Cole, Jefferson
Subject: RE: Weekly Team Biomass meeting

Thanks Bill. We would like to discuss that with you. As I am just back and getting into the swing of things, I will email you when we are ready.
Sara

From: Irving, Bill
Sent: Thursday, May 29, 2014 10:09 AM
To: Ohrel, Sara; Cole, Jefferson
Subject: RE: Weekly Team Biomass meeting

I'm ok with canceling.

Also, let me know if you want to discuss OAQPS/OGC comments on appendix A.

From: Ohrel, Sara
Sent: Thursday, May 29, 2014 10:02 AM
To: Kocchi, Suzanne; Fawcett, Allen; Irving, Bill; Cole, Jefferson; Smith, Eric; Sherry, Christopher; Wirth, Tom
Subject: RE: Weekly Team Biomass meeting

Hi all,
We will cancel this meeting for the broader group unless you have items you wish to discuss. If so, please let me know.
Thanks!

-----Original Appointment-----
From: Ohrel, Sara
Sent: Wednesday, January 08, 2014 2:56 PM
To: Kocchi, Suzanne; Fawcett, Allen; Irving, Bill; Cole, Jefferson; Smith, Eric; Sherry, Christopher; Wirth, Tom; DCRoom1310L956p20PCPoly/DC-1310L-OAR
Subject: Weekly Team Biomass meeting
When: Thursday, May 29, 2014 10:30 AM-11:00 AM (UTC-05:00) Eastern Time (US & Canada).
Where: DCRoom1310L956p20PCPoly/DC-1310L-OAR

Standing meeting in case we need it for biomass.

From:	Ohrel, Sara
To:	Kocchi, Suzanne
Sent:	5/13/2014 11:40:23 AM
Subject:	RE: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

Fair enough – read too fast and thought it was about our revised draft.

-----Original Message-----
From: Kocchi, Suzanne
Sent: Tuesday, May 13, 2014 11:25 AM
To: Ohrel, Sara
Subject: RE: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

We've talked about what SAB has said before publicly. That is what Juan said, reminding them what SAB has said about the feestocks.

-----Original Message-----
From: Ohrel, Sara
Sent: Tuesday, May 13, 2014 11:03 AM
To: Kocchi, Suzanne; Irving, Bill; Fawcett, Allen; Cole, Jefferson
Cc: Gunning, Paul
Subject: RE: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

Thank you for the heads up. Just FYI – His use of the last point (- ie waste ok, forest/ag need more work) marks the first time we have stated that externally.

-----Original Message-----
From: Kocchi, Suzanne
Sent: Tuesday, May 13, 2014 10:55 AM
To: Irving, Bill; Fawcett, Allen; Ohrel, Sara; Cole, Jefferson
Cc: Gunning, Paul
Subject: FW: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

Everyone is going to be on this call correct?

Juan just left me a voicemail about this so we wouldn't be surprised/know the plan. He is planning to lead the call (since AF&PA will be in the room with them). He will call on us if needed about the framework but in order to manage the meeting (and given he apparently has talked to them recently about all this) he just wanted to be sure we knew he was going to do most of the talking.

He also said to demonstrate progress he has already used the talking point with them that "we are working on the revised framework based on SAB and stakeholder input" So AF&PA know there is work underway on the framework. Juan has also used the talking points about the SAB feedstock on the different feedstock categories (- ie waste ok, forest/ag need more work).

-----Original Message-----
From: Long, Pam
Sent: Monday, May 12, 2014 12:14 PM
To: Johnson, Yvonne W; Santiago, Juan; Wood, Anna; Kornylak, Vera S.; Gunning, Paul; Kocchi, Suzanne; Ohrel, Sara; Irving, Bill; Fawcett, Allen; Cole, Jefferson
Subject: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

See below.

-----Original Message-----
From: Hunt, Tim [mailto:Tim_Hunt@afandpa.org]
Sent: Tuesday, May 06, 2014 12:30 PM
To: Johnson, Yvonne W
Cc: Bradfield, John; Santiago, Juan
Subject: RE: Accepted: Juan, Linda, Tim call on 5/13 AF&PA-AWC planning

Yvonne,

Here are some questions that form an agenda of sorts for next week. We reviewed them with Juan today so none of them should be a surprise. We welcome any questions in advance to help us prepare for the meeting to make it a fruitful as possible for everyone. See you in a week's time.

Tim

II. Biogenic CO2 (60 minutes) with Juan Santiago, Anna Wood and staff – 2 to 3 PM

1. Please provide an update on the timing of PSD/BACT biogenic proposal relative to the proposed Accounting Framework.
2. Discuss suggested PSD regulatory framework provided on April 14
3. Discuss definition of "forest products manufacturing residuals" provided February 21st
4. Address questions related to April 14 legal bases for the EPA to exempt from PSD permitting biogenic CO2 emissions from the use of forest products manufacturing residuals for energy.
5. Review any precedents set in recent PSD permits involving biogenic emissions.
6. Discuss how burning biomass might be addressed in the upcoming existing EGU GHG NSPS proposal?

From:	Ohrel, Sara
To:	Cole, Jefferson
Sent:	5/12/2014 5:09:34 PM
Subject:	RE: main doc
Attachments:	DRAFT Framework_Master_3-28-14_CH_VK4 RTI_so15_C2.docx

Yes, here it is. thanks!

From: Cole, Jefferson
Sent: Monday, May 12, 2014 4:57 PM
To: Ohrel, Sara
Subject: main doc

Hey Sara,

When you have a chance, could you shoot over the version of the main doc that I should review?

Thanks,

Jeff

_____

Jefferson Cole
Economist
Climate Change Division
U.S. EPA
202.343.9671
cole.jefferson@epa.gov

From:	Kocchi, Suzanne
To:	Ohrel, Sara
Sent:	5/13/2014 11:42:45 AM
Subject:	RE: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

Yes, obviously we don't know what exactly Juan has said but just as we have we done when we
talk about the SAB feedback the implication is that by stressing that feedback is that we
agree with them and/or are strongly considering them.

-----Original Message-----
From: Ohrel, Sara
Sent: Tuesday, May 13, 2014 11:40 AM
To: Kocchi, Suzanne
Subject: RE: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

Fair enough - read too fast and thought it was about our revised draft.

-----Original Message-----
From: Kocchi, Suzanne
Sent: Tuesday, May 13, 2014 11:25 AM
To: Ohrel, Sara
Subject: RE: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

We've talked about what SAB has said before publicly. That is what Juan said, reminding them
what SAB has said about the feestocks.

-----Original Message-----
From: Ohrel, Sara
Sent: Tuesday, May 13, 2014 11:03 AM
To: Kocchi, Suzanne; Irving, Bill; Fawcett, Allen; Cole, Jefferson
Cc: Gunning, Paul
Subject: RE: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

Thank you for the heads up. Just FYI - His use of the last point (- ie waste ok, forest/ag
need more work) marks the first time we have stated that externally.

-----Original Message-----
From: Kocchi, Suzanne
Sent: Tuesday, May 13, 2014 10:55 AM
To: Irving, Bill; Fawcett, Allen; Ohrel, Sara; Cole, Jefferson
Cc: Gunning, Paul
Subject: FW: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

Everyone is going to be on this call correct?

Juan just left me a voicemail about this so we wouldn't be surprised/know the plan. He is
planning to lead the call (since AF&PA will be in the room with them). He will call on us if
needed about the framework but in order to manage the meeting (and given he apparently has
talked to them recently about all this) he just wanted to be sure we knew he was going to do
most of the talking.

He also said to demonstrate progress he has already used the talking point with them that "we
are working on the revised framework based on SAB and stakeholder input" So AF&PA know there
is work underway on the framework. Juan has also used the talking points about the SAB
feedstock on the different feedstock categories (- ie waste ok, forest/ag need more work).

-----Original Message-----
From: Long, Pam
Sent: Monday, May 12, 2014 12:14 PM
To: Johnson, Yvonne W; Santiago, Juan; Wood, Anna; Kornylak, Vera S.; Gunning, Paul; Kocchi,
Suzanne; Ohrel, Sara; Irving, Bill; Fawcett, Allen; Cole, Jefferson
Subject: More info. for the AF&PA-AWC meeting on 5/13 from 2-3pm

See below.

-----Original Message-----
From: Hunt, Tim [mailto:Tim_Hunt@afandpa.org]
Sent: Tuesday, May 06, 2014 12:30 PM
To: Johnson, Yvonne W
Cc: Bradfield, John; Santiago, Juan
Subject: RE: Accepted: Juan, Linda, Tim call on 5/13 AF&PA-AWC planning

Yvonne,

Here are some questions that form an agenda of sorts for next week. We reviewed them with Juan today so none of them should be a surprise. We welcome any questions in advance to help us prepare for the meeting to make it a fruitful as possible for everyone. See you in a week's time.

Tim

II. Biogenic CO2 (60 minutes) with Juan Santiago, Anna Wood and staff – 2 to 3 PM

1. Please provide an update on the timing of PSD/BACT biogenic proposal relative to the proposed Accounting Framework.
2. Discuss suggested PSD regulatory framework provided on April 14
3. Discuss definition of "forest products manufacturing residuals" provided February 21st
4. Address questions related to April 14 legal bases for the EPA to exempt from PSD permitting biogenic CO2 emissions from the use of forest products manufacturing residuals for energy.
5. Review any precedents set in recent PSD permits involving biogenic emissions.
6. Discuss how burning biomass might be addressed in the upcoming existing EGU GHG NSPS proposal?

Sara,

I'd also asked Katie about this and she pointed me to a report she'd prepared for you that indicates the amount of

Ex. 5 - Deliberative

Ex. 5 - Deliberative

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Thursday, May 08, 2014 12:50 PM
To: Beach, Robert H.
Subject: RE: cofire

Perfect. I just need a link to the site where the underlying biomass cofire information is from (cofire only not 100% biomass entities)– can you send that? From EIA or eGRID I think?

From: Beach, Robert H. [mailto:rbeach@rti.org]
Sent: Thursday, May 08, 2014 12:48 PM
To: Ohrel, Sara
Subject: RE: cofire

I think these are the files where the information was pulled together and using the 2009 EIA-923 dataset like you thought.

Based on these data, about:

Does that answer the question?

Robert

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Thursday, May 08, 2014 12:31 PM
To: Beach, Robert H.
Subject: cofire

Limited amount of biomass co-firing currently practiced in the U.S.

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

Hi team,

I want to thank you all for the hard work, critical thinking, and monumental effort that you have put forth over the course of the last four months, and even more so over the last few weeks. I have seen nothing but the highest degrees of professionalism, dedication, and teamwork from you. I am proud of all that we have accomplished and hope that you are too.

Sincerely,
Sara

From: Ohrel, Sara
Sent: Thursday, May 01, 2014 4:33 PM

Hello everyone,

Attached you will find the updated package of the *Framework for Assessing Biogenic CO2 Emissions from Stationary Sources* for your review. This package includes:

- SAB Response Document
- Framework Main Report
- Appendix A: IPCC Inventory Approach to Accounting for All Anthropogenic Greenhouse Gas Emissions
- Appendix B: Temporal Scale
- Appendix C: Spatial Scale
- Appendix D: Feedstock Categorization and Definitions
- Appendix E: Discussion of Leakage Literature
- Appendix F: General Algebraic Representation of the Biogenic Assessment Factor Equations
- Appendix G: Biogenic Process Attributes
- Appendix H: Illustrative Biogenic Landscape Attributes Using a Retrospective Reference Point Baseline
- Appendix I: Illustrative Forestry and Agriculture Case Studies using a Retrospective Reference Point Baseline
- Appendix J: Anticipated Baselines: Background and Key Modeling Considerations
- Appendix K: Future Anticipated Baseline Construction: Methodology and Results
- Appendix L: Illustrative Forestry and Agriculture Case Studies using a Future Anticipated Baseline
- Appendix M: Summary of Illustrative Forestry and Agriculture Results
- Appendix N: Assessing Biogenic CO2 Emissions from Waste-Derived Feedstocks

We appreciate your help and time with this review. We request that all comments are submitted by the close of business May 15th. We will be in touch soon to schedule an initial meeting (as we understand that more may be required) during

the week of May 12 to discuss any questions that may arise during your review. Please share with anyone in your group that I may have missed.

Thank you,
Sara on the behalf of CCD's Team Biomass

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Baker, Justin
To:	Ohrel, Sara; Cole, Jefferson
Sent:	5/1/2014 12:13:40 PM
Subject:	RE:
Attachments:	Framework_Master_5 01 2014_clean_Final.docx

Dear all,

Here is a clean version of the framework document.

Justin

From: Baker, Justin
Sent: Thursday, May 01, 2014 11:31 AM
To: 'Ohrel, Sara'; 'Cole, Jefferson'
Subject: RE:

Dear all,

Here is an clean and edited version of App J.

Justin

From: Baker, Justin
Sent: Thursday, May 01, 2014 8:31 AM
To: 'Ohrel, Sara'; Cole, Jefferson
Subject: RE:

This is what I get for waking up at 2:00 in the morning and trying to work!

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Thursday, May 01, 2014 8:30 AM
To: Baker, Justin; Cole, Jefferson
Subject: RE:

Thanks. I was just about to ask you how this one was different from what I sent.

From: Baker, Justin [mailto:justinbaker@rti.org]
Sent: Thursday, May 01, 2014 8:28 AM
To: Cole, Jefferson; Ohrel, Sara
Subject: RE:

Apologies, but please disregard this one as Sara had sent me a clean version yesterday.

We just need to confirm that the remaining "fuel shed" has been edited to be "fuelshed"

Sorry for my mix-up on this one.

From: Baker, Justin
Sent: Thursday, May 01, 2014 8:21 AM
To: 'Cole, Jefferson'; 'Ohrel, Sara'

Cc: Beach, Robert H.
Subject: RE:

Adding "spatial scale" to the list. Here is a clean and edited version of App C.

From: Baker, Justin
Sent: Thursday, May 01, 2014 3:33 AM
To: 'Cole, Jefferson'; 'Ohrel, Sara'
Cc: Beach, Robert H.
Subject: RE:

And here is App I.

From: Baker, Justin
Sent: Thursday, May 01, 2014 3:10 AM
To: 'Cole, Jefferson'; Ohrel, Sara
Cc: Beach, Robert H.
Subject: RE:

Sara and Jeff,

Attached are Apps D and E, from RTP to Bogotá and on to you.

Jeff—see section 5.2 of the Leakage App. There was a comment indicating that this section may have been left out of a previous version of the appendix that was sent to you.

Justin

From: Cole, Jefferson [mailto:Cole.Jefferson@epa.gov]
Sent: Thursday, May 01, 2014 12:30 AM
To: Baker, Justin; Ohrel, Sara
Subject: RE:

Justin,

I've made a couple minor text edits to Appendix F. I've attached both a track changes version and a clean version.

Thanks,

Jeff

From: Baker, Justin <justinbaker@rti.org>
Sent: Wednesday, April 30, 2014 11:39 AM
To: Ohrel, Sara; Cole, Jefferson
Subject: RE:

Attached is the edited version of App F.

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Wednesday, April 30, 2014 11:28 AM
To: Baker, Justin; Cole, Jefferson
Subject: RE:

Perfect, thank you Justin.

From: Baker, Justin [mailto:justinbaker@rti.org]
Sent: Wednesday, April 30, 2014 11:24 AM
To: Ohrel, Sara; Cole, Jefferson
Subject:

this email and all attachments are deliberative

Dear Sara and Jeff,

Please find edited versions of Appendices A, K, and L for your final review. I wanted to send these along as I know that Jeff was looking over Appendix L this morning.

Thanks, and I will be sending additional appendices throughout the day.

Justin

PS, RTI is saving draft versions as well that include all comments, but I don't want to flood your inbox with those until we've finished editing.

Justin S. Baker, Ph.D.
Senior Economist
Agricultural, Resource & Energy Economics and Policy Program
Global Climate Change and Environmental Sciences Unit
RTI International
3040 Cornwallis Road
P.O. Box 12194
Research Triangle Park, NC 27709-2194
Phone: (919) 541-6933   Fax: (919) 541-7155
Email: justinbaker@rti.org

From:	Cole, Jefferson
To:	Baker, Justin; Ohrel, Sara
Sent:	5/1/2014 12:28:37 AM
Subject:	RE:
Attachments:	Appendix_K_Future Anticipated Baseline Construction Methodology and Results_clean_Final_JC.docx; Appendix_K_Future Anticipated Baseline Construction Methodology and Results_clean_Final_JCclean.docx

Justin,

Thanks for sending these. I have no edits for Appendix A.

For Appendix K, I made one small edit (a page break), and some comments on a couple charts. These are not mission critical comments, just nice to have for the next round.

I've attached a track change version and a clean version.

Best,

Jeff

From: Baker, Justin <justinbaker@rti.org>
Sent: Wednesday, April 30, 2014 11:23 AM
To: Ohrel, Sara; Cole, Jefferson
Subject:

this email and all attachments are deliberative

Dear Sara and Jeff,

Please find edited versions of Appendices A, K, and L for your final review. I wanted to send these along as I know that Jeff was looking over Appendix L this morning.

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Justin

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Justin S. Baker, Ph.D.
Senior Economist
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P.O. Box 12194
Research Triangle Park, NC 27709-2194
Phone: (919) 541-6933   Fax: (919) 541-7155
Email: justinbaker@rti.org

From:	Baker, Justin
To:	Cole, Jefferson; Ohrel, Sara
CC:	Beach, Robert H.
Sent:	5/1/2014 3:09:49 AM
Subject:	RE:
Attachments:	Appendix_D_Feedstock Categories_04 28 14_clean_Final.docx; Appendix_E_Discussion of Leakage Literature_clean_Final.docx

Sara and Jeff,

Attached are Apps D and E, from RTP to Bogotá and on to you.

Jeff—see section 5.2 of the Leakage App. There was a comment indicating that this section may have been left out of a previous version of the appendix that was sent to you.

Justin

From: Cole, Jefferson [mailto:Cole.Jefferson@epa.gov]
Sent: Thursday, May 01, 2014 12:30 AM
To: Baker, Justin; Ohrel, Sara
Subject: RE:

Justin,

I've made a couple minor text edits to Appendix F. I've attached both a track changes version and a clean version.

Thanks,

Jeff

From: Baker, Justin <justinbaker@rti.org>
Sent: Wednesday, April 30, 2014 11:39 AM
To: Ohrel, Sara; Cole, Jefferson
Subject: RE:

Attached is the edited version of App F.

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Wednesday, April 30, 2014 11:28 AM
To: Baker, Justin; Cole, Jefferson
Subject: RE:

Perfect, thank you Justin.

From: Baker, Justin [mailto:justinbaker@rti.org]
Sent: Wednesday, April 30, 2014 11:24 AM
To: Ohrel, Sara; Cole, Jefferson
Subject:

this email and all attachments are deliberative

Dear Sara and Jeff,

Please find edited versions of Appendices A, K, and L for your final review. I wanted to send these along as I know that Jeff was looking over Appendix L this morning.

Thanks, and I will be sending additional appendices throughout the day.

Justin

PS, RTI is saving draft versions as well that include all comments, but I don't want to flood your inbox with those until we've finished editing.

Justin S. Baker, Ph.D.
Senior Economist
Agricultural, Resource & Energy Economics and Policy Program
Global Climate Change and Environmental Sciences Unit
RTI International
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P.O. Box 12194
Research Triangle Park, NC 27709-2194
Phone: (919) 541-6933   Fax: (919) 541-7155
Email: justinbaker@rti.org

From:	Hanks, Katie P.
To:	Ohrel, Sara
CC:	Cole, Jefferson; Baker, Justin
Sent:	4/30/2014 11:26:55 PM
Subject:	Appendix G
Attachments:	Appendix_G_Process Attributes 4 30 2014-clean_Final.docx

The final appendix G is attached.

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

From:	Baker, Justin
To:	Ohrel, Sara
Sent:	4/30/2014 10:36:42 AM
Subject:	RE: Process Attributes Appendix-- Deliberative
Attachments:	DRAFT Appendix F_Process Attributes 4 30 2014.docx

Try this version.

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Wednesday, April 30, 2014 10:31 AM
To: Baker, Justin
Subject: RE: Process Attributes Appendix-- Deliberative

Hi Justin,
Something is wrong with this document. I cannot save it once I start editing, cant change the title etc. just lost some time.
Can you play around with this and/or send me another version?

From: Baker, Justin [mailto:justinbaker@rti.org]
Sent: Tuesday, April 29, 2014 4:50 PM
To: Ohrel, Sara; Cole, Jefferson
Cc: Hanks, Katie P.; McGrath, Meaghan
Subject: Process Attributes Appendix-- Deliberative

Dear Sara and Jeff,

I've attached an updated draft of the process attributes appendix. As we've discussed, we may want to

Ex. 5 - Deliberative

Let us know if you have any questions.

Thanks,
Justin

Justin S. Baker, Ph.D.
Senior Economist
Agricultural, Resource & Energy Economics and Policy Program
RTI International
3040 Cornwallis Road
P.O. Box 12194
Research Triangle Park, NC 27709-2194
Phone: (919) 541-6933   Fax: (919) 541-7155
Email: justinbaker@rti.org

Hello team,
After a long haul, here is the draft main doc for RTI review and editing team. Two versions: the one ending in C2 is cleaned with only comments remaining (RTI can delete those this round)(I lost C1 and had to start over – boo). And the other one is the big, beauty mess underlying the clean version for reference if needed later (as some comments were deleted as I accepted deletions in the text).

Justin, in the clean version, I have highlighted specific comments and requests to RTI in neon green (there aren't too many; just a few citation requests and other general formatting things). Also, I have no idea how I did it, but somehow when I had 1.1.1 titles (header 3), it comes up black…must have modified my settings somehow.

After this, likely in the am, I will turn to L&P and Ref Pt Landscape Atts (I just got from ICF).

Thanks & good night,
Sara

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Ohrel, Sara
Sent:	4/29/2014 4:59:41 PM
Subject:	doc - deliberative
Attachments:	DRAFT Framework_Master_3-28-14_CH_VK4 RTI_so15_C2.docx

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

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Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Ohrel, Sara
Sent:	4/29/2014 10:42:13 AM
Subject:	doc- deliberative
Attachments:	DRAFT Framework_Master_3-28-14_CH_VK4 RTI_so13.docx

Sara Bushey Ohrel
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--this email is deliberative--do not distribute or cite--

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

Sara and Jeff,

Here's the updated App D, reflecting the latest comments that you had provided in commented and clean versions. For some reason, I can't get the files to save in the project folder from here, but Justin or Sharon could you please place these in the correct folder(s) with the clean one in the ready for PSG folder?

Thanks,
Robert

Robert H. Beach, Ph.D.
Director
Agricultural, Resource & Energy Economics and Policy Program
Global Climate Change and Environmental Sciences Unit
RTI International
3040 Cornwallis Road
P.O. Box 12194
Research Triangle Park, NC 27709-2194
Phone: (919)485-5579   Fax: (919)541-7155
Email: rbeach@rti.org   Website: www.rti.org/rbeach

Adjunct Assistant Professor
Department of Agricultural and Resource Economics
North Carolina State University
Email: rhbeach@ncsu.edu

From:	Ohrel, Sara
To:	Sara Bushey Ohrel
Sent:	4/26/2014 7:08:46 PM
Subject:	Fw: Ref Pt landscape attributes app - deliberative
Attachments:	App D Feedstock Categories 4 26 14_comments.docx

Sent from my BlackBerry 10 smartphone.

From: Beach, Robert H.
Sent: Saturday, April 26, 2014 6:50 PM
To: Ohrel, Sara; Cole, Jefferson
Cc: Latta, Greg; Baker, Justin
Subject: RE: Ref Pt landscape attributes app - deliberative

Hi Sara and Jeff,

Here is an updated version of App D, with additions/revisions from Jeff Coburn, Katie Hanks, Greg, and I. Does this adequately respond to all the comments you'd had on the previous version? Just let me know if there's anything else you'd like us to address and then we can send a clean and marked up version ready for editing back to you and to our editors simultaneously.

Thanks,
Robert

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Saturday, April 26, 2014 6:38 PM
To: Latta, Greg; Baker, Justin
Cc: Cole, Jefferson; Beach, Robert H.
Subject: Re: Ref Pt landscape attributes app - deliberative

No worries, thanks Greg! I will take a look and let you know if I have questions. If I don't, we can send in for the RTI editing team.
Have a nice weekend,
Sara

Sent from my BlackBerry 10 smartphone.

From: Latta, Greg
Sent: Saturday, April 26, 2014 3:48 PM
To: 'Baker, Justin'; Ohrel, Sara
Cc: Cole, Jefferson; 'Beach, Robert H.'
Subject: RE: Ref Pt landscape attributes app - deliberative

All,

Here is the corrected **Ex. 5 - Deliberative**
Ex. 5 - Deliberative

Sorry it took so long for me to get back to it.

Greg

From: Baker, Justin [mailto:justinbaker@rti.org]
Sent: Friday, April 25, 2014 2:11 PM
To: Latta, Greg; 'Ohrel, Sara'

Cc: 'Cole, Jefferson'; Beach, Robert H.
Subject: RE: Ref Pt landscape attributes app - deliberative

Thanks, Greg and Sara.

I'll send this to editing now.

From: Latta, Greg [mailto:greg.latta@oregonstate.edu]
Sent: Friday, April 25, 2014 4:58 PM
To: 'Ohrel, Sara'; Baker, Justin
Cc: 'Cole, Jefferson'; Beach, Robert H.
Subject: RE: Ref Pt landscape attributes app - deliberative

Here you go.

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Friday, April 25, 2014 1:13 PM
To: Latta, Greg; Justin Baker (justinbaker@rti.org)
Cc: Cole, Jefferson; Robert H. Beach (rbeach@rti.org)
Subject: Ref Pt landscape attributes app - deliberative

Hi crew,
Attached you will find two versions of the ref pt landscape attributes app:
- One is a clean version with comments that I sent to ICF today to work on references and other general editing.
- The other (v2) builds off the above with additional comments and edits from me today (much easier to edit after cleaning out all the tracked 'garbage'.

It is looking really good - now with the vast tracts of tracked changes removed, I can really appreciate how much better it flows, so thanks Greg. And thanks to you and Justin for helping [**Ex. 5 - Deliberative**] mid-week.

I have a few clarifying questions for Greg to address in v2 (and a few items flagged for us to add next round so no need to worry about those, yet). Greg, if you can address those today, we can then send it along to the editing team, so please let me know if you can.

Thank you!

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

Hi Justin,

Attached are my comments on the FABA baseline construction app. Looking good. I have made some edits and comments, including some comments I would like you to address - these i have highlighted with green text. most will be quick, a couple more involved. please let me know if you have any questions or want to discuss.

once you are done with those edits, please send 2 copies (tracked and clean) to EPA and your editing team.

Thank you!
Sara

From:	Ohrel, Sara
To:	Ohrel, Sara
Sent:	4/24/2014 9:22:52 AM
Subject:	main doc deliberative
Attachments:	DRAFT Framework_Master_3-28-14_CH_VK4 7_so10.docx

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Mangino, Joseph
To:	Ohrel, Sara
Sent:	4/23/2014 2:22:41 PM
Subject:	regualatory approaches pieces with edit
Attachments:	PossibleRegulatoryApproachesBiogenicCO2_4-23-2014.docx

Sara, per our conversation today...attached is the piece with the revised last bullet under item #5.

Thanks for taking a look again and let me know what you think.

-Joe

Joe Mangino
U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Policy Division
Research Triangle Park, NC
919-541-9778 (phone)

Note: Positions or views expressed here do not represent official EPA policy. Interagency deliberative and confidential.

Deliberative

Hi Michelle,

Nice to catch up with you last week!

Here is the draft feedstock cat. list. **This is not final.**

Ex. 5 - Deliberative

we should be able to get you a draft AF2 in a week or two.

And attached are some of the reports.

Everything in this email is deliberative and confidential. Please do not discuss outside your core team.

THANKS!
Sara

-----Original Message-----
From: Michelle Manion [mailto:Michelle_Manion@abtassoc.com]
Sent: Wednesday, April 16, 2014 4:02 PM
To: Ohrel, Sara
Subject: Follow-up from today

Hi Sara,

Thanks for the meeting today--talking through some of the definitional challenges for the key categories was really helpful.

Here's the list of items for you to send us:
1) List of categories from the Accounting Framework;
2) Revised Accounting Framework (when available); and

3) You mentioned a few relevant reports from NAFO, NCASI, and AF&PA.

Jerry Franklin is the forest ecologist at the University of Washington I mentioned. I believe his expertise is more on the ecology of fire in western forests (esp. Pacific NW), but he is probably as good a sounding board as anyone on the issue of fuel treatments and their likely impact on the incidence and severity of forest fires.

Here's a link to his info: http://faculty.washington.edu/jff/index.htm

I'll probably be back down again in early May; if so, I'll let you know.

Thanks!

--Michelle

Michelle Manion| Senior Associate | Abt Associates
55 Wheeler Street, Cambridge MA 02138
T: 617.520.2379|C: 617.631.2015| E: Michelle_Manion@abtassoc.com

www.abtassociates.com

-----Original Message-----
From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Wednesday, April 16, 2014 9:15 AM
To: Michelle Manion
Cc: Cole, Jefferson
Subject: RE: 9:30 meeting place

Great, see you soon! Jeff will be joining me.

-----Original Message-----
From: Michelle Manion [mailto:Michelle_Manion@abtassoc.com]
Sent: Wednesday, April 16, 2014 9:14 AM
To: Ohrel, Sara
Subject: 9:30 meeting place

Hi Sara,
I couldn't find a Caribou Coffee at 13th and G, (I think it may now be Peet's, but it isn't open yet). I'm at the Lawson's on G St.
Thanks,
Michelle
Cell: 617.631.2015

Sent from my iPhone

February 21, 2014

Joseph Goffman
Senior Counsel, Office of Air and Radiation
USEPA Headquarters
Ariel Rios Building
1200 Pennsylvania Avenue, N. W.
Mail Code: 1101A
Washington, DC 20460

Re: Alternative Fates of Forest Products Manufacturing Residuals

Dear Mr. Goffman:

At our November 25, 2013 meeting, you and EPA staff mentioned that it would be helpful to your development of the Biogenic CO2 Accouting Framework if we provided information on the alternative fates of forest products manufacturing residuals if they were not used for energy.

In October 2013, the National Council for Air and Stream Improvement (NCASI) issued Technical Bulletin 1016, titled "Greenhouse gas and fossil fuel reduction benefits of using biomass manufacturing residuals for energy production in forest products facilities." NCASI summarizes in Table 1 the alternative fate scenarios used in the NCASI study described in Technical Bulletin 1016 and provides additional background material on each residual type.

Table 1. Typical Alternative Fates Considered in NCASI Studies*

Residuals Type	Landfill	Incinerated
Kraft black liquor	0%	100%
Woody mill residues	100%	0%
WWTP residuals	66%	34%
Paper recycling residuals	96%	4%

* See attached memorandum for information reqarding the quantities of biomass residuals and management types.

Spent pulping liquor (kraft black liquor)
At present, to NCASI's knowledge, all kraft black liquor produced in the U.S. is combusted in chemical recovery systems which (a) regenerate the pulping chemicals and (b) produce steam which is used in combined heat and power systems to produce electricity and steam used in the production process. Black liquor recovery is integral to the economic feasibility of the kraft pulping process (the process responsible for 93% of the chemical- and semi-chemical-pulping in the U.S. according to AF&PA data).

In NCASI's research it was assumed that if not used in the chemical recovery process, kraft black liquor would either be incinerated or treated in wastewater treatment systems. In both cases, all of the carbon would be released as biogenic CO_2. In NCASI's research, the emission reduction benefits estimated for combusting black liquor in the kraft recovery system are based on CO_2 emissions. The range of benefits would be higher if the alternative management scenario resulted in some of the carbon being released as methane.

Woody mill residuals (e.g. sawdust, bark)
As you know, the creation and use of biomass energy in forest products mills is integral and incidental to the manufacture of products such as pulp, paper, packaging and wood products. To the extent feasible, the wood biomass entering the mills is used to create these higher value products. The remaining manufacturing residuals are used to power the mills and provide electricity for the grid.

AF&PA and American Wood Council (AWC) surveys show that large amounts of woody mill residuals are used for energy. The amounts not combusted for energy or used in pulp, paper, packaging and wood products, but disposed of, are so small that the AF&PA and AWC surveys do not attempt to separate them from other miscellaneous wastes produced in pulp, paper and wood products manufacturing. If woody mill residuals are disposed of, they are reported in the "Other" waste category in the AF&PA survey and the "Total Residuals" category of the AWC survey. Combining the "Other" wastes in the AF&PA survey with the "Total Residuals" category in the AWC survey, one finds that, 94% of these materials are landfilled and 6% incinerated. It is NCASI's experience where woody mill residuals are not used for energy, it is because they are unsuitable for combustion due to high moisture content or contamination with rocks and non-combustible debris. These circumstances also make the materials difficult to incinerate. Therefore, it is reasonable to assume that, at present, where woody mill residuals are not being used for energy or otherwise beneficially used (e.g. a small amount of bark is sold as mulch), they are being landfilled.

In the NCASI study, the data show that almost all woody mill residuals not now used for energy or other beneficial uses are being landfilled. Therefore, 100% landfilling was considered as the alternative fate for woody mill residuals in the event that the industry could not combust them for energy or other beneficial uses.

In modeling the landfilling of these materials, NCASI used EPA decay parameters, in some cases updated with more current research, and EPA modeling methods. It was assumed that the landfills receiving woody mill residuals were not capped to collect and destroy methane as there are currently extremely few, if any, mill landfills in the U.S. equipped with gas collection and incineration systems.

Wastewater treatment plant (WWTP) residuals
Data collected in AF&PA surveys indicate that approximately one-half in the industry's WWTP residuals are beneficially used via combustion for energy, land applying and other means. For the one-half of WWTP residuals not beneficially used, but disposed of, 66% are sent to landfills and 34% are incinerated (without energy recovery). For this reason, NCASI assumed that if the amounts now being used for energy had to be managed by some other means, 66% would be sent to landfills and 34% would be incinerated. As noted above, landfilling was modeled using accepted models and parameters, and landfills were assumed not be equipped with methane capture and incineration systems. Incineration emissions were modeled as being the same as the emissions from comustion for energy.
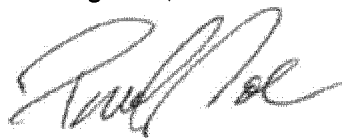
Paper recycling residuals
AF&PA does not collect data specifically on the management of recycling residuals. Where these materials are disposed of, they are reported in the "Other" waste category. (The AWC survey is not relevant as paper recycling residuals are not generated at wood products plants.) The AF&PA survey data for "Other" wastes indicate that when disposed of, 94% of these materials are landfilled and 6% are incinerated. Therefore, NCASI assumed that for those recycling residuals now being used for energy, if a different management practice was required, 94% would be landfilled and 6% would be incinerated. The methods used to model these practices were the same as described above for WWTP residuals.

Attached is another memorandum dated December 6, 2013 which contains a more detailed description of the data available to characterize current management practices for the industry's manufacturing residuals.

Thank you again for taking the time to discuss these important issues that EPA and the forest products industry are facing. Please contact me if you have any questions.

Best regards,

Paul Noe
Vice President, Public Policy

Enclosure

cc: Paul Gunning
        Sara Ohrel
        Juan Santiago

ncasi

Caroline Gaudreault, Ph.D.
Senior Research Scientist
Chercheure Sénior
(514) 286-1182

December 06, 2013

TO: Reid Miner

cc: Kirsten Vice, Laurel Epstein, Bill Thacker, Barry Malmberg

FROM: Caroline Gaudreault

SUBJECT: Available Information on Manufacturing Residuals

INTRODUCTION

NCASI has published a series of reports on the greenhouse benefits of using biomass residuals for energy production in industry facilities (NCASI 2013, 2011; Gaudreault et al. 2012). The studied residuals include:

1) black liquor;
2) woody mill residuals (e.g., bark and sawdust);
3) wastewater treatment plant (WWTP) residuals; and
4) paper recycling residuals (materials removed during processing of recovered paper to eliminate contaminants and yield reusable fiber that generally consist of a fiber and plastic fraction e.g., Old Corrugated Containers (OCC) rejects).

The studies are informed by data from surveys undertaken every two years by the American Forest & Paper Association (AF&PA) and the American Wood Council. The surveys collect data on the environmental and energy performance of US forest products facilities (AF&PA 2010; AWC 2010). These surveys are the main source of information on the management of biomass manufacturing residuals generated by US forest products industry facilities. The material below describes how the survey data have been used to estimate the current management practices for manufacturing residuals and to develop non-use (alternative fate) scenarios for NCASI's studies of the GHG impacts of using these residuals for energy.

MATERIALS BURNED FOR ENERGY

In cases where facilities use manufacturing residuals for energy, they need to report them under the "Biomass and Renewable Energy" section of the AF&PA/AWC surveys.

Table **1** establishes the correspondence between the "Biomass and Renewable Energy" categories of the AF&PA/AWC surveys and the types of manufacturing residuals analyzed by NCASI. In three of four cases, there are direct connections between the residuals examined in the NCASI reports and the categories in the industry surveys. In one case, "paper recycling residuals", there is no direct connection to survey categories.

Table 1. Correspondence Between AF&PA/AWC Biomass and Renewable Energy Categories and Type of Manufacturing Residuals Analyzed by NCASI

Residuals Type Analyzed by NCASI in Studies of Energy from Manufacturing Residuals	AF&PA/AWC Survey: Biomass and Renewable Energy Category
Black liquor	Spent liquor solids*
Woody mill residuals	Hogged fuel, self-generated, manufacturing residues Hogged fuel, purchased, manufacturing residues
WWTP residuals	WTP residuals (sludge)
Paper recycling residuals	Other *No single category corresponds to paper recycling residuals. These residuals would be included in the category of "other" which includes many things besides paper recycling residuals.*
Not included in NCASI studies	Hogged fuel, self-generated, logging residues Hogged fuel, purchased, logging residues Self-generated hydroelectricity Non-recyclable paper

Almost all of this is black liquor solids. Kraft pulping, which produces black liquor, represents about 95% of all pulping of the type that produces spent liquor solids (AF&PA 2011). Other types of pulping that produce spent pulping liquors are sulfite pulping and semi-chemical pulping.

RESIDUALS DISPOSAL PRACTICES

In cases where pulp and paper facilities dispose of the biomass residuals instead of using them for energy, they need to report them under the "Residuals Management" section of the AF&PA survey. Since 2010, wood product facilities no longer report residuals management as what they generate is mostly woody mill residuals beneficially used (AWC 2012, 2010). The last time wood product facilities reported residuals management was in 2008 (AWC 2008) and they reported all residual types combined.

Table **2** shows the relationships between the surveys "Residuals Management" categories and alternative fates assigned to the residuals in NCASI's studies.

Table **3**, shows the correspondence between the residuals types covered in these surveys and those analyzed by NCASI. As depicted in **Table 2**, other options for processing or using the biomass residuals (e.g., torrefaction, gasification, hydrolysis and

fermentation, other beneficial uses) were not analyzed by NCASI because the objective of the series of NCASI studies on residuals study was to contrast their use for energy with their disposal. Also, as shown in

Table 3, the AF&PA survey does not provide an option for reporting black liquor under "Residuals Management".

Table 2. Correspondence Between AF&PA/AWC Residuals Management Categories and Alternative Fates Analyzed in by NCASI

AF&PA/AWC Residuals Management Category	Alternative Fate Assigned by NCASI
Landfilled and/or lagoon	Landfill
Burned on-site*	Incineration
Beneficially applied to land	N/A[1]
Otherwise beneficially used	N/A

Facilities are required not to include hogged fuel or purchased materials (bark, old tires, waste oil, etc.) burned for energy, as they are accounted for in the biomass and renewable energy section of the survey.

Table 3. Correspondence Between AF&PA/AWC Residuals Types and Those Analyzed by NCASI

AF&PA/AWC Residuals Management Survey Description	Residuals Type Analyzed by NCASI
Treatment plant residuals	WWTP residuals
Ash	N/A
N/A	Black liquor
Others, pulp and paper (includes causticizing wastes, general mill trash, construction debris, OCC rejects, landfilled broke, bark, wood residuals, sawdust, knots, metal and other recyclable)	Paper recycling residuals, woody mill residuals
Total residuals from wood product facilities (includes ashes, woodyard residuals, woody mill residuals not including residuals burned on-site for energy)	Woody mill residuals

QUANTITIES OF RESIDUALS USED FOR ENERGY AND DISPOSED OF

Table 4 presents the quantities of woody mill residuals, black liquor, WWTP residuals and paper recycling residuals generated by management type. Data are for 2010 unless otherwise specified.

---

[1] N/A: Not applicable.

- 4 -

Table 4. Quantities of Biomass Residuals and Management Types

Residuals Type	Burned for Energy	Landfilled	Incinerated	Land Applied	Otherwise Beneficially Used
	bone-dry short tons				
Black liquor	65,993,292*	N/A	N/A	N/A	N/A
Woody mill residues	22,688,924†	N/Av.[2]	N/Av.	N/Av.	N/Av.
WWTP residuals	729,320‡	1,579,902	820,923	670,376	485,625
Paper recycling residuals	16,787§	N/Av.	N/Av.	N/Av.	N/Av.
Others, pulp and paper facility**	N/A	2,325,842	160,457	343,344	571,844
Total residuals, wood product facilities††	N/A	164,445	315	127,325	4,045,638‡‡

*Estimated using 13.4 MMBtu HHV/st. †Estimated using 17.2 MMBtu HHV/st.‡Estimated using 12.8 MMBtu HHV/st. §Estimated to be 4% of other residuals used for energy, 23.9 MMBtu HHV/st. **Includes causticizing wastes, general mill trash, construction debris, OCC rejects, landfilled broke, bark, wood residual, sawdust, knots, metal and other recyclable. ††2008 data. ‡‡Includes residuals sent for products off-site.

NCASI ASSUMPTIONS REGARDING RESIDUALS ALTERNATIVE FATE
NCASI used the quantities landfilled and incinerated presented in **Table 4**, as well as other information, to model typical alternative fates for residuals when not used for energy. These are summarized in Table .

In the case of black liquor, because for all intents and purposes it is always managed in the kraft recovery system to produce energy and pulping chemicals, a detailed model of alternative fate would have been highly speculative. However, the alternative fate would almost certainly involve returning the biogenic carbon in the liquor to the atmosphere. In the best case from a greenhouse gas emission standpoint, it would return as CO_2, so this is what was modeled assuming incineration (Gaudreault et al. 2012; NCASI 2011).

Regarding woody mill residuals, as shown in

Table 3, they would fall into the "Others" category of the AF&PA survey or "total residuals" of the AWC survey, which together are 94% landfilled and 6% incinerated if not used for energy or beneficially used. However, given that woody mill residuals generated in forest product facilities are typically burned for energy recovery, it is unlikely that the 6% incinerated includes woody biomass. For this reason, 100% landfilling was considered as the typical alternative fate. It should be noted however, that there are very few data on what would be a reasonable "typical" alternative fate for woody mill residuals as it is not a common practice of the industry to dispose of these.

---

[2] N/Av.: Not available.

Data in **Table 4** were used directly to derive the alternative fate of WWTP residuals and "Others" from pulp and paper mills were considered representative of paper recycling residuals.

Table 5. Typical Alternative Fates Considered in NCASI Studies

Residuals Type	Landfill	Incinerated
Black liquor	0%	100%
Woody mill residues	100%	0%
WWTP residuals	66%	34%
Paper recycling residuals	96%	4%

REFERENCES

American Forest & Paper Association (AF&PA). 2010. Pulp and Paper Mill 2010 Environment, Fuel &Energy and Health Survey. Washington, DC.

American Forest & Paper Association (AF&PA). 2011. *2010 Annual Statistical Summary - Paper, Paperboard and Pulp*. Washington D.C.: AF&PA.

American Wood Council (AWC). 2008. Wood Products AWC 2008 Environment, Fuel and Energy Survey. Washington, DC.

American Wood Council (AWC). 2010. Wood Products AWC 2010 Environment, Fuel and Energy Survey. Washington, DC.

American Wood Council (AWC). 2012. Wood Products AWC 2012 Environment, Fuel and Energy Survey. Washington, DC.

Gaudreault, C., B. Malmberg, B. Upton, and R. Miner. 2012. Life cycle greenhouse gases and non-renewable energy benefits of kraft black liquor recovery. *Biomass and Bioenergy* 46(0): 683-692.

National Council for Air and Stream Improvement, Inc. (NCASI). 2011. *Greenhouse Gas and Non-Renewable Energy Benefits of Black Liquor Recovery*. Technical Bulletin No. 984. Research Triangle Park, NC: National Council for Air and Stream Improvement, Inc.

National Council for Air and Stream Improvement, Inc. (NCASI). 2013. *Greenhouse gas and fossil fuel reduction benefits of using biomass manufacturing residuals for energy production in forest products manufacturing facilities*. Technical Bulletin no. 1015. Research Triangle Park, NC: National Council for Air and Steam Improvement, Inc.

From:	Cole, Jefferson
To:	Ohrel, Sara
Sent:	4/21/2014 4:51:31 PM
Subject:	RE: feedstock categories
Attachments:	Appendix D - Feedstock Categories - 4 02 14 Clean_jbc_rhb so_v2_jc.docx

Sara,

Two small comments from me.

1.

2.

Ex. 5 - Deliberative

I've attached my edited file.

Thanks!

Jeff

From: Ohrel, Sara
Sent: Monday, April 21, 2014 12:20 PM
To: Cole, Jefferson
Subject: feedstock categories
Importance: High

Hi Jeff,
Please review the waste section of the attached appendix. It should not take too long. Also, **(b)(5) deliberative**
(b)(5) deliberative if so, add what you can today, but we will send
it to RTI to finish filling in by COB today (please send it to me when you are done, as I am drafting up an email with
instructions for them).
Thanks!

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Justin Baker (justinbaker@rti.org)
CC:	Robert H. Beach (rbeach@rti.org); Cole, Jefferson
Sent:	4/21/2014 5:32:13 PM
Subject:	feedstock categorization
Attachments:	App D Feedstock Categories 4 2 14 Clean_jbc_rhb so_v2_jc_so.docx

Hi all,

Attached is the recent draft of the feedstocks categorization document. Mostly we just need ⌐**Ex. 5 - Deliberative**⌐ ⌐**Ex. 5 - Deliberative**⌐ Please take a look and let me know who can work on this and when you hope to get it back to us/the editing team (meaning you can send us a marked up draft and a clean draft at the same time you send it to the editing team).

Thanks!

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From: Weitz, Melissa
Sent: Friday, April 18, 2014 5:09 PM
To: Ohrel, Sara
Subject: RE: Review of various biogenic CO2 framework documents

Hi Sara,

Some questions/comments/edits on appendix L. Let me know if you'd like to discuss.

Melissa

From: Ohrel, Sara
Sent: Thursday, April 17, 2014 4:31 PM
To: Weitz, Melissa
Subject: RE: Review of various biogenic CO2 framework documents

Marvelous – thank you so much!

From: Weitz, Melissa
Sent: Thursday, April 17, 2014 4:24 PM
To: Ohrel, Sara
Subject: RE: Review of various biogenic CO2 framework documents

Hi Sara,

My comments on appendix H are included in the attached. I made some edits to areas that didn't make sense to me, to write them in a way that did make sense, though I may definitely be interpreting some things wrong, so feel free to ignore!

Melissa

From: Ohrel, Sara
Sent: Wednesday, April 02, 2014 5:14 PM
To: Weitz, Melissa
Cc: Irving, Bill; Cole, Jefferson
Subject: Review of various biogenic CO2 framework documents

Hi Melissa,

Bill has informed us that you will be reviewing some components of the biogenic CO2 framework. Attached you will find the draft future anticipated baseline background appendix as well as the baseline construction appendix. If you could please send us your comments by Monday 4/14, that would be greatly appreciated.

Please let us know if you have any questions.

Thank you for your time and help!
Sara

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

Sara,

The latest draft of the black liquor paper is attached. I addressed your 2[nd] round of comments in redline and accepted changes on the first comments that were already fixed.

Ex. 5 - Deliberative

Please let me know if you have any questions.

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Thursday, April 10, 2014 8:59 AM
To: Hanks, Katie P.
Cc: Baker, Justin
Subject: RE: Black liquor fate paper revisions

Looking good. some minor edits/questions in the attached. Can we have a quick chat today (half hour) about this and next steps? I am available at 12-1 and 2-3.

From: Hanks, Katie P. [mailto:kphanks@rti.org]
Sent: Wednesday, April 09, 2014 4:45 PM
To: Ohrel, Sara
Cc: Baker, Justin
Subject: Black liquor fate paper revisions

My revisions to the black liquor paper are attached with my responses (in yellow) in the comment bubbles. We can eliminate the bubbles when you are ready.

I will start looking over the ICF memo, the black liquor Case 3 in the AF1 document, and the NCASI comment from October 2011 relative to Case 3. The information provided in the attached paper did not consider these prior documents.

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

From:	Ohrel, Sara
To:	Ohrel, Sara
Sent:	4/17/2014 2:20:16 PM
Subject:	AF2 deliberative
Attachments:	DRAFT Framework_Master_3-28-14_CH_VK4 7_so5.docx

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Justin Baker (justinbaker@rti.org)
CC:	Robert H. Beach (rbeach@rti.org); Cole, Jefferson; Greg Latta
Sent:	4/12/2014 1:57:50 PM
Subject:	process attributes draft app (L and P) - deliberative
Attachments:	Appendix F process attributes 3 19 14v2_4 12 14.docx; Appendix F.docx; Chapter_11__Miranowski__Economics_o_5CB8228405177.pdf; TO 003_DRAFT_Appendix D_01-28-2012.docx

Hi Justin,

What you have been waiting for – process attributes!

I have reorganized and refocused the app, and I hope that it flows better and ultimately makes sense (been looking at it a while so I am no longer sure). I had some issues trying to save it during edits today (yikes moment) – managed to save it but lost tracked changes. I will send the recent, cleaner version ('Appendix F') and an earlier one so you can see how things have/have not changed if needed ("Appendix F process attributes….4 12 14').

Changes:
-
-

Ex. 5 - Deliberative

-

I am available most of Monday for a chat, so we can discuss LOE, staffing, balancing with other items currently with RTI

Ex. 5 - Deliberative

Thank you!

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Hanks, Katie P.
To:	Ohrel, Sara
CC:	Cole, Jefferson; Baker, Justin
Sent:	4/10/2014 4:36:01 PM
Subject:	NCASI TB 984
Attachments:	tb984_Benefits_of_Bl_Liquor_2011.pdf

The April 2011 NCASI technical bulletin I mentioned on the phone today is attached.

Greenhouse gas and non-renewable energy benefits of black liquor recovery. Technical Bulletin No. 984.

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

ncasi

NATIONAL COUNCIL FOR AIR AND STREAM IMPROVEMENT

GREENHOUSE GAS AND

NON-RENEWABLE ENERGY BENEFITS

OF BLACK LIQUOR RECOVERY

TECHNICAL BULLETIN NO. 984

APRIL 2011

by
Caroline Gaudreault, Ph.D.
NCASI Canada
Montreal, Quebec

Barry Malmberg, Ph.D. and Brad Upton, Ph.D.
NCASI Western Regional Center
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serving the environmental research needs of the forest products industry since 1943

PRESIDENT'S NOTE

In several recent announcements, the Environmental Protection Agency has made known its interest in understanding the life cycle greenhouse gas benefits associated with using biomass in order to support the development of various programs governing the use of biomass and releases of greenhouse gases. The decisions EPA makes on this topic have the potential to increase greatly the costs of doing business as well as to impair the perception of industry's products in the marketplace. The forest products industry, therefore, has a great deal at stake in ensuring that the agency's deliberations on this topic are well informed.

Black liquor solids comprise about half of the fuel used by the pulp and paper industry. Yet, among the various types of biomass used by the industry, the life cycle benefits of using black liquor solids are the least well understood, having been essentially ignored in the life cycle studies of biomass published to date. To remedy this lack of understanding of the life cycle greenhouse gas and non-renewable energy benefits of using black liquor solids in the kraft recovery system, NCASI undertook such a study, the results of which are contained in this report.

In this study, NCASI has compared a system using black liquor solids in the kraft recovery system to a fossil-fuel based system providing an equal amount of energy as well as chemicals for pulping. The results indicate that fossil fuel-related greenhouse gas emissions and non-renewable energy consumption are approximately 90% lower when black liquor solids are used in the kraft recovery system than in a comparable fossil fuel-based system. More than half of the benefits are attributable to the highly efficient production of pulping chemicals from black liquor solids in the kraft recovery system.

Based on 2004 data, approximately 100 million tonnes of fossil-fuel derived CO_2 emissions are avoided per year by using black liquor solids at US kraft mills. These avoided greenhouse gas emissions are approximately equal to the total of the forest products industry's emissions from fossil fuel combustion plus the emissions from electric power companies attributable to electricity purchased by the industry. These results do not depend on the accounting method for biogenic carbon (because biogenic CO_2 emissions are the same for the systems compared) and the results are valid across a range of assumptions.

This study is one of a series of ongoing NCASI projects having the objective of helping the forest products industry and its stakeholders better understand the greenhouse gas and energy impacts of using forest biomass as a raw material and fuel.

Ronald A. Yeske

April 2011

National Council for Air and Stream Improvement

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MOT DU PRÉSIDENT

Dans plusieurs annonces récentes, l'Agence de protection de l'environnement des États-Unis (EPA) a fait connaître son intérêt pour la compréhension des avantages liés à de l'utilisation de la biomasse en ce qui concerne les émissions de gaz à effet de serres et ce, en adoptant une approche cycle de vie. Ceci à pour but de soutenir le développement de divers programmes régissant l'utilisation de la biomasse et les émissions de gaz à effet de serre reliées. Les décisions potentielles de l'EPA sur ce sujet ont le potentiel d'accroître considérablement les coûts pour les entreprises ainsi que de nuire à la perception des produits de biomasse dans le marché. L'industrie des produits forestiers, par conséquent, a intérêt à ce que les délibérations de l'EPA sur ce sujet soient bien informées.

Les solides de la liqueur noire représentent environ la moitié du carburant utilisé par l'industrie des pâtes et papiers. Pourtant, parmi les différents types de biomasse utilisés par l'industrie, les avantages du cycle de vie de l'utilisation des matières solides de la liqueur noire sont les moins bien compris. En effet, à ce jour, essentiellement aucune étude n'a été publiée à ce sujet. Pour remédier à ce manque de compréhension des avantages cycle de vie (gaz à effet de serre et énergie non-renouvelable) de l'utilisation des solides de la liqueur noire dans le cycle de récupération des produits chimiques de la pâte kraft, NCASI a entrepris une telle étude, dont les résultats sont contenus dans le présent rapport.

Dans cette étude, NCASI a comparé un système utilisant les solides de la liqueur noire dans le système de récupération des produits chimiques de la pâte kraft à un système produisant la même quantité d'énergie et de produits chimiques, mais à partir de combustible fossiles. Les résultats indiquent que la récupération de la liqueur noire réduit les émissions gaz à effet de serre de source fossile et la consommation d'énergie non-renouvelable d'environ 90%. Plus de la moitié de cette réduction est généralement attribuable à la production efficace de produits chimiques de mise en pâte dans le cycle de récupération de la liqueur noire.

Sur la base de données de 2004, environ 100 millions de tonnes d'émissions de CO_2 de source fossile fossiles sont évitées par an en utilisant les solides de la liqueur noire dans les usines de pâte kraft aux États-Unis. Ces émissions évitées de gaz à effet de serre sont à peu près égales au total des émissions de l'industrie des produits forestiers provenant de la combustion de combustibles fossiles ainsi qu'aux émissions dues à la production de l'électricité qu'elle achète. Ces résultats ne dépendent pas de la méthode de comptabilisation du carbone biogénique (parce que les émissions de CO_2 biogénique sont les mêmes pour les deux systèmes comparés) et sont valides pour toute une gamme d'hypothèses.

Cette étude fait partie d'une série de projets de NCASI dont l'objectif est d'aider l'industrie des produits forestiers et ses intervenants à mieux comprendre les émissions de gaz à effet de serre et la consommation d'énergie attribuables à l'utilisation de la biomasse forestière en tant que matière première et source d'énergie.

Ronald A. Yeske

Avril 2011

GREENHOUSE GAS AND NON-RENEWABLE ENERGY BENEFITS OF BLACK LIQUOR RECOVERY

TECHNICAL BULLETIN NO. 984
APRIL 2011

ABSTRACT

In this study, the life cycle greenhouse gas (GHG) and fossil fuel benefits of black liquor recovery are analyzed. These benefits are due to two effects: the production of energy that can be used in the pulping process or sold, and the recovery of the pulping chemicals that would otherwise need to be produced from other resources.

The fossil GHG emissions and non-renewable energy consumption for a system using black liquor solids in the kraft recovery system are approximately 90% lower than those for a comparable fossil fuel-based system. Across all scenarios, the systems relying on black liquor solids achieve a median reduction of approximately 140 kg CO_2 eq./GJ of energy produced, compared to the systems relying on fossil fuels to provide the same energy and pulping chemical production functions. The benefits attributable to the recovery of pulping chemicals vary from 44% to 75% of the total benefit. Applied to the total production of kraft pulp in the US, the avoided emissions are enough to offset all of the total Scope 1 and Scope 2 emissions from all mills in the US forest products industry. These results do not depend on the accounting method for biogenic carbon (because biogenic CO_2 emissions are the same for the systems compared) and the results are valid across a range of assumptions about the displaced fossil fuel, the GHG intensity of the grid, the fossil fuels used in the lime kiln, and the level of cogeneration at pulp and paper mills. The benefits occur without affecting the amount of wood harvested or the amount of chemical pulp produced.

KEYWORDS

black liquor, energy, greenhouse gases, life cycle assessment

RELATED NCASI PUBLICATIONS

None

AVANTAGES POUR LES ÉMISSIONS DE GAZ À EFFET DE SERRE ET LA CONSOMMATION D'ÉNERGIE NON RENOUVELABLE DE LA RÉCUPÉRATION DE LA LIQUEUR NOIRE

BULLETIN TECHNIQUE NO. 984
AVRIL 2011

RÉSUMÉ

Dans cette étude, les avantages de la récupération de la liqueur noire pour les émissions de gaz à effet de serre (GES) et la consommation d'énergie non renouvelable sont analysés en utilisant une approche cycle de vie. Deux causes permettent d'expliquer ces avantages : la production d'énergie pouvant être utilisée dans la fabrication de la pâte et du papier ou vendue, ainsi que la récupération des produits chimiques de mise en pâte qui, autrement, devraient être produits à partir d'autres ressources.

Les émissions de GES et la consommation d'énergie fossile non renouvelable pour un système utilisant les solides de la liqueur noire dans le système de récupération des produits chimiques de la pâte kraft sont environ 90% inférieurs à ceux d'un système comparable à base de combustibles fossiles. Lorsque tous les scénarios analysés sont pris en compte, la récupération de la liqueur noire produit une réduction moyenne d'environ 140 kg de CO_2 équivalents par gigajoule d'énergie produite, par rapport à un système produisant la même quantité d'énergie et de produits chimiques de mise en pâte, mais à partir de combustibles fossiles. Les avantages attribuables spécifiquement à la production de produits chimiques de mise en pâte varient entre 44% et 75% du total. Lorsqu'appliquées à la production totale de pâte kraft aux États-Unis, les émissions évitées sont suffisantes pour compenser la totalité des émissions de Scope 1 et de Scope 2 de l'industrie américaine des produits forestiers. Ces résultats ne dépendent pas de la méthode de comptabilisation du carbone biogénique (parce que les émissions de CO_2 biogénique sont les mêmes pour les deux systèmes comparés) et sont valables pour toute une gamme d'hypothèses incluant le type de combustibles fossiles déplacé, les émissions de GES produites par le réseau électrique, les combustibles fossiles utilisés dans les fours à chaux et le niveau de cogénération dans les usines de pâtes et papiers. Les avantages observés se produisent sans affecter la quantité de bois récolté ou la quantité de pâte chimique produite.

MOTS CLÉS

Liqueur noire, énergie, gaz à effet de serre, analyse du cycle de vie

PUBLICATIONS DE NCASI RELIÉES

Aucune

National Council for Air and Stream Improvement

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GREENHOUSE GAS AND NON-RENEWABLE ENERGY BENEFITS
OF BLACK LIQUOR RECOVERY

1.0 INTRODUCTION

Recent years have seen both a rise in the interest in substituting biomass for fossil fuels and increasing skepticism about the greenhouse gas (GHG) benefits of this substitution. While programs that promote the use of biomass as a substitute for fossil fuel have important connections to the issues of energy security and economic sustainability, it is the questions about greenhouse gas mitigation benefits that have been at the center of the debate on whether and how to increase the reliance on the use of biomass for energy.

An important distinction between biomass carbon and the carbon in fossil fuels is that the carbon in biomass-derived fuels was only recently removed from the atmosphere. When biomass is burned, decays, or is otherwise oxidized, the resulting CO_2 is returned to the atmosphere. This aspect of the biogenic carbon cycle forms the basis for using a zero emission factor at the point of combustion for biomass-derived fuels (Abbasi and Abbasi 2010; Cherubini 2010; Cherubini et al. 2009; Lattimore et al. 2009; Robinson, Rhodes, and Keith 2003), and it represents an accepted benefit of using biomass-derived fuels rather than fossil fuels (Abbasi and Abbasi 2010; Froese et al. 2010; Schlamadinger et al. 1997). This is recognized by the ISO series of standards on life cycle assessment (ISO 2003, 35):

> *"The characterization model that describes the net-zero C emitted when burning biomass fuel is typically a recycling model, in which CO_2 from the atmosphere (and its C expression) are sequestered by the photosynthesis process [...]. [...] the CO_2 emissions from the combustion are considered equal to those already sequestered and those that will be subsequently sequestered. This is different from the CO_2 emissions of fossil fuel that result from the use of C from long-term carbon sinks rather than from the atmosphere. The characterization factor used is 0."*

There is a difference between the life cycle impacts (i.e., "footprint") of a biomass fuel and the emission factor (for an emissions inventory) of a biomass fuel. The emission factor of a biomass fuel pertains only to emissions that occur at the point of combustion. Life cycle impacts are based on these point of combustion emissions in combination with "upstream" (e.g., land use change, silvicultural/harvesting, transport, processing) and "downstream" (e.g., end-of-life) emissions. Because of these upstream, non-combustion emissions, the life cycle impacts assigned to biomass fuel use can be non-zero even where the release of biogenic CO_2 upon combustion is in balance with carbon uptake via regrowth (Abbasi and Abbasi 2010; Cherubini 2010). Where the amounts of CO_2 that return to the atmosphere are less than the amounts removed, the difference represents increases in stocks of stored carbon (net removals from the atmosphere). Where net returns are greater than the amounts removed, the difference represents depleted stocks of stored carbon.

There are different types of biomass used for energy and different regimes of land use/carbon stock changes associated with them. Biomass fuels obtained from residuals (agricultural, manufacturing, forestry residuals, etc.) are typically not associated with land use/carbon stock changes (Cherubini 2010; Mann and Spath 2001; Schlamadinger et al. 1997). Manufacturing residuals include many things such as wood manufacturing residues (e.g., bark, sawdust, planer shavings, sander dust from sawmills, panel plants, and pulp and paper mills, including material in on-site bark/hog piles).

Recent life cycle assessment (LCA) studies of wood residue-based energy systems, summarized in Table 1.1, typically demonstrate significant greenhouse gas mitigation benefits compared to energy derived from fossil fuels. Wood residues investigated in these studies included forest residuals (Cherubini et al. 2009; Froese et al. 2010; Mann and Spath 2001; Pehnt 2006; Robinson, Rhodes, and Keith 2003), mill residues (Mann and Spath 2001; Petersen Raymer 2006), urban "waste," or demolition wood (Mann and Spath 2001; Pehnt 2006; Petersen Raymer 2006).

Table 1.1 Life Cycle GHG Mitigation Benefits for Wood-Based Residues Energy Systems

Study	Biofuel Type	Fossil Fuel Offset	GHG Mitigation[a]
Froese et al. 2010	Forest residuals	Coal electricity (cofiring)	100%
Mann and Spath 2001	Various woody residuals	Coal electricity (cofiring)	123%[b]
Robinson et al. 2003	Forest and agriculture residues	Coal electricity (cofiring)	$\approx 95\%$
Pehnt 2006	Forest wood, woody biomass energy crops, waste wood	Energy mix in Germany for electricity generation and home heating in 2010	85-95%
Cherubini et al. 2009	Forest residuals	Various fossil fuels used for heat and electricity production	70-98%
Petersen Raymer 2006	Fuel wood, sawdust, wood pellets, demolition wood, briquettes, bark	Coal electricity (cofiring) and heating oil	81-98%

[a] Percent for base case; for cofiring situations the mitigation pertains to the cofire rate (e.g., if 10% fossil fuel is replaced by biomass and emissions decrease by 9%, mitigation of 90% is assigned).
[b] Mitigation greater than 100% due to avoided end-of-life methane emissions.

Black liquor solids, a by-product of the kraft pulping process, account for approximately half of the fuel used by the pulp and paper industry (AF&PA 2010). Yet, even in a time when the industry and its stakeholders are anxious to understand the benefits of using biomass fuels, there has been no comprehensive life cycle-based assessment of the benefits of using black liquor solids. Having identified this information need, NCASI recently undertook a life cycle study of the greenhouse gas and non-renewable energy impacts of using black liquor solids in the kraft recovery system. This report contains the results of that study.

2.0 GOAL AND SCOPE OF THE LIFE CYCLE STUDY

Life Cycle Assessment (LCA) is a *"compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle,"* the life cycle being *"consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal"* (ISO 2006a, 2).

LCA principles and methodology are framed by a set of standards (ISO 2006a, 2006b) and technical report specifications (ISO 2000, 2002, 2003) from the International Organization for Standardization (ISO). ISO describes LCA methodology in four phases (as illustrated in Figure 2.1):

1) **Goal and scope definition** in which the aim of the study, the product system under study, its function and functional unit, the intended audience, and the methodological details on how the study will be performed are defined;

2) **Life cycle inventory analysis (LCI)** which is the *"phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle"* (ISO 2006a, 2);

3) **Life cycle impact assessment (LCIA)** which is the *"phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product"* (ISO 2006a, 2); and

4) **Life cycle interpretation** which is the *"phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations"* (ISO 2006a, 2).
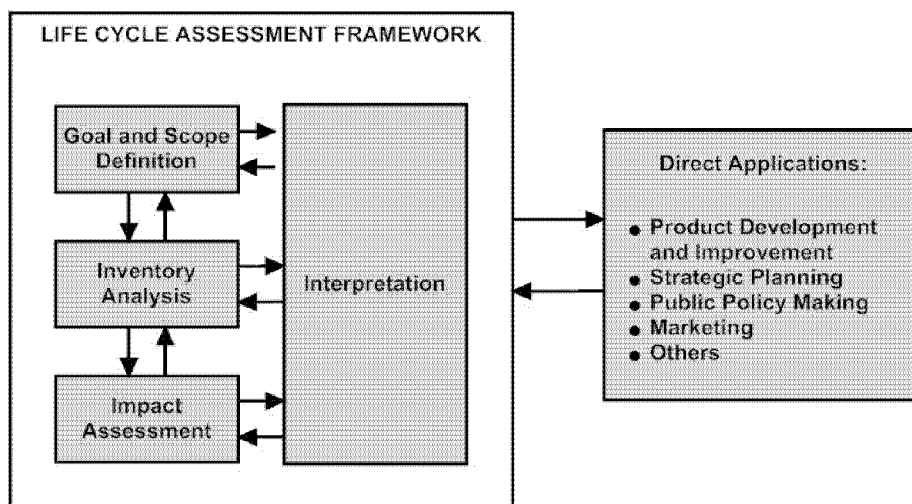
Figure 2.1 Life Cycle Assessment Phases (ISO 2006a)

In this study, a simplified (streamlined) LCA methodology has been applied. Streamlining generally can be accomplished by limiting the scope of the study or simplifying the modeling procedures, thereby limiting the amount of data or information needed for the assessment (Todd and Curran 1999). Many different streamlining approaches can be applied. In this study, two main approaches were taken: limiting the impact assessment to two indicators (global warming, life cycle non-renewable energy demand), and using mainly site-generic information to model the fossil fuel system. Because of this, the study does not fully comply with ISO 14044 requirements for comparative assertions disclosed publically. However, the study aligns as much as possible with this standard.

2.1 Objective of the Study

The objective of this study is to characterize the GHG and non-renewable energy conservation benefits of using black liquor solids for energy production when compared to the GHGs from the fossil fuel it replaces.

2.2 Function and Functional Unit

The ISO 14044 standard requires that *"the scope of an LCA shall clearly specify the functions (performance characteristics) of the system being studied"* and that the *"functional unit shall be consistent with the goal and scope of the study"* (ISO 2006b, 8). The objective of this study is to

compare two alternative ways of producing energy (function) and the primary functional unit is defined as *the production of 1 GJ of energy (heat and power)[1]*.

The production of energy using black liquor solids results in secondary functions that need to be dealt with. This is discussed below.

2.3   Description of the Systems Compared, System Boundaries, and Allocation

The methodology used in this study follows life cycle principles, by calculating emissions from "cradle to final energy" including end conversion efficiency. In other words, it is extended beyond the point of combustion to include transformation into electricity/steam (including transformation efficiency and distribution losses where applicable). Two different systems are compared and discussed hereinafter: a system in which 1 GJ of energy is produced from black liquor solids and an equivalent system in which the same amount of energy is produced from fossil fuels.

2.3.1   *Black Liquor Product System*

2.3.1.1   *Description of the Product System*

A schematic of the kraft pulping process is presented in Figure 2.4. Kraft pulping involves cooking wood chips in an aqueous solution of pulping chemicals, resulting in the extraction of cellulose from the wood by dissolving the lignin that binds the cellulose fibers together. In the kraft process, white liquor containing sodium hydroxide (NaOH) and sodium sulfide (Na_2S) is used to cook the chips in digesters at elevated temperature and pressure. The cooked chips are blown from the digester and washed to separate the spent cooking chemicals and dissolved organics, which together comprise "black liquor solids," from the fibers. The black liquor solids are sent for further processing in the kraft recovery system. The recovery system is critical to the economic viability of kraft pulping. It has two main functions: the recovery and regeneration of the inorganic pulping chemicals, and the combustion of the dissolved organic material with recovery of the energy content as process steam and electrical power. In some cases, it is also used to recover valuable organic by-products such as turpentine and tall oil.

Weak black liquor from pulp washing is sent to multiple-effect evaporators to increase its solids content to around 50%. The evaporation process requires a significant amount of energy. The resulting strong (concentrated) black liquor is sent to concentrators to increase the solids content further to between 65 and 80% (some older mills use direct contact evaporators instead of concentrators to increase the solids content to about 65%). The black liquor solids are then burned in a furnace known as a recovery boiler. Energy is produced in the oxidative zone of the boiler from organic matter in the liquor. This energy drives the chemical reactions in the reduction zone of the furnace, converting spent pulping chemicals into a molten smelt. Kraft black liquor solids are typically generated at a rate of between 1,300 and 1,900 kg of dry solids per metric tonne of pulp (2,600 to 3,800 lb/short ton). They have a higher heating value, ranging from about 12.6 to 15.2 GJ/tonne of black liquor solids (5,400 to 6,600 Btu/lb), so they are a significant source of energy for the pulp mill. Generally, the high pressure steam produced from recovery boilers is used to generate electricity through a process called combined heat and power (CHP) or cogeneration. With CHP or cogeneration, the high pressure steam turns a turbine to make electricity. Useful thermal energy (low or medium pressure steam) is also extracted from the turbine and used in the manufacturing process.

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[1] The heat to power ratio depends on the mill scenario investigated and is equivalent in the two systems compared.
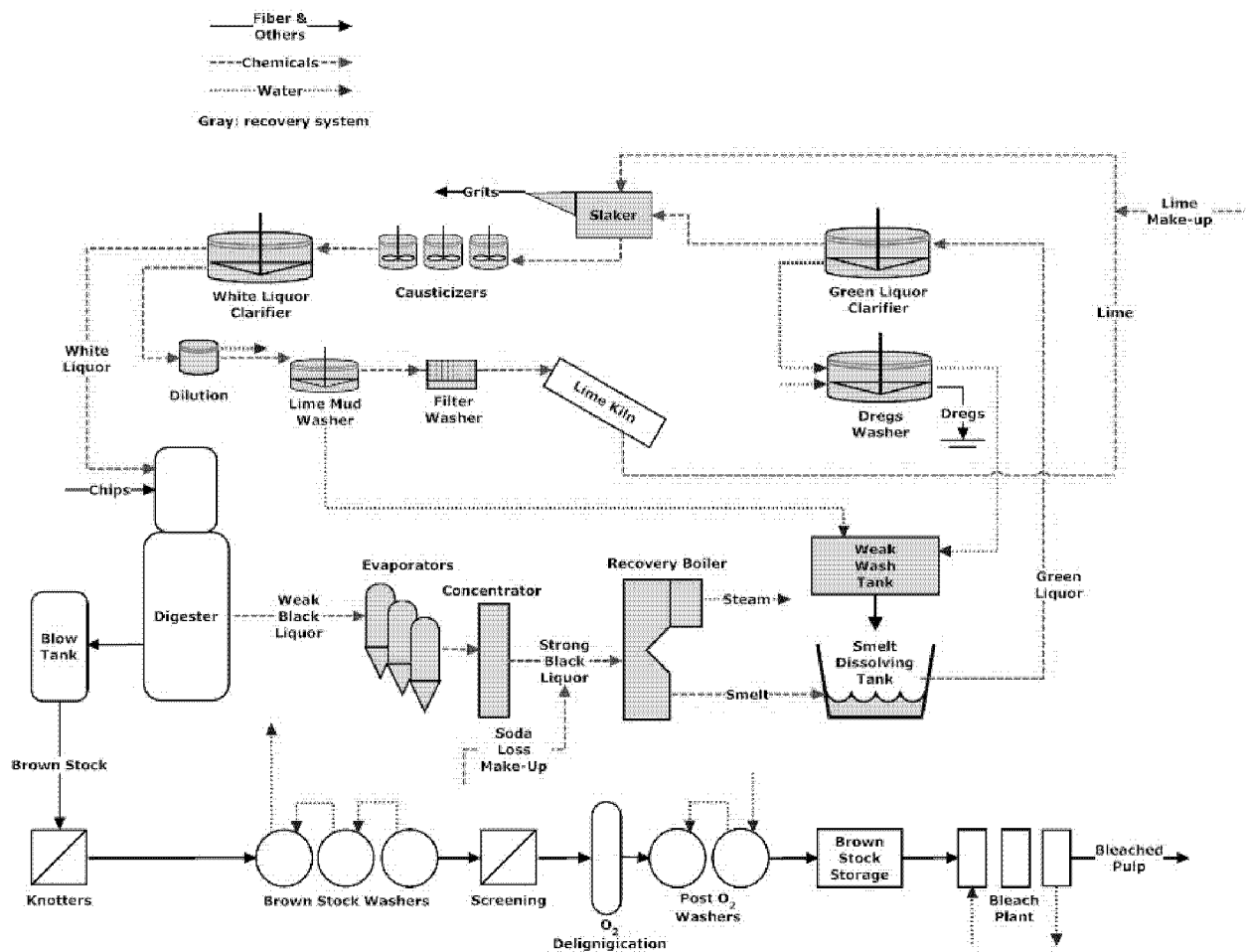
Figure 2.2 Flow Diagram of a Typical Kraft Pulping Process, Including Recovery and Bleaching
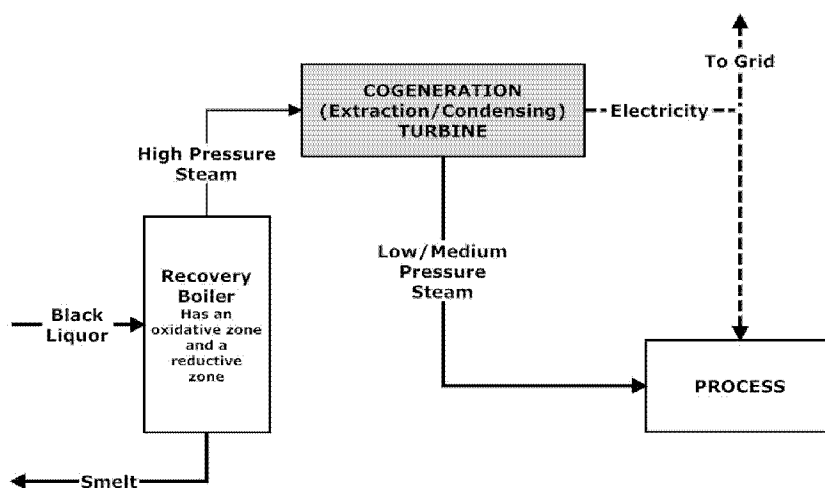
Figure 2.3 Cogeneration from Steam Produced in Recovery Boilers

The smelt, containing mainly sodium sulfide and sodium carbonate, is dissolved in weak wash (from the mud washing system) in the smelt dissolving tank to produce green liquor. The green liquor is clarified to remove solids (green liquor dregs) and sent to the slaker, which is then followed by a series of causticizers. Reburned lime (CaO) from the lime kiln (see below) or fresh lime is added to the slaker where it is slaked to form calcium hydroxide. The calcium hydroxide reacts with sodium carbonate present in the green liquor within the causticizers to form sodium hydroxide and calcium carbonate, the latter precipitating due to its low solubility. The resulting white liquor is clarified to remove calcium carbonate (lime mud) and inerts (slaker grits) prior to being sent to the pulp mill for use in the digester. The lime mud from the clarifier is washed, filtered, and sent to the lime kiln to convert calcium carbonate back into calcium oxide for reuse in the slaker. In the lime kiln, lime mud (about 55% to 80% calcium carbonate, with the balance being water) is calcined to form lime (CaO) and CO_2. The source of heat for this reaction is typically natural gas or fuel oil. Occasionally, petroleum coke is also used. A simplified representation of the chemistry in the kraft pulping and chemical recovery system is illustrated in Figure 2.4.
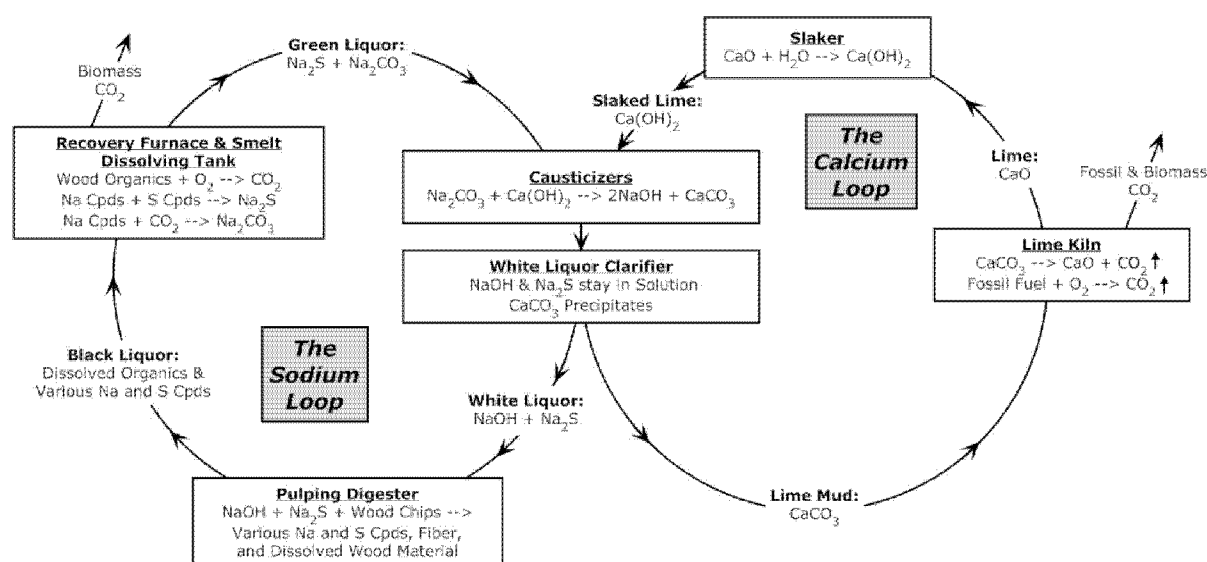
Figure 2.4 Chemistry of the Kraft Pulping Process

2.3.1.2 *System Boundary and Allocation*

When performing an LCA, the product system needs to be defined and the system boundary established. When several products (or functions) from different product systems share the same unit process or group of unit processes, an allocation problem is encountered. The allocation problem consists of the need to attribute the environmental load among each of the products (or functions) delivered by the shared process, which are sometimes referred to as multifunctional processes. Two types of co-products can be differentiated: co-products that are used within the investigated system, and co-products that are used in other product systems.

Several strategies can be used when an allocation problem is encountered. The ISO 14044 standard (ISO 2006b) on LCA recommends the following hierarchy of approaches, in preferential order:

1) Avoid allocation through
   a. System subdivision or
   b. System expansion;
2) Perform allocation using an underlying physical relationship; or
3) Perform allocation using another relationship.

When applying the ISO 14044 standard, system subdivision and system expansion strategies should be selected over allocation wherever possible. System expansion is possible and advantageous in this context, so it is applied. The advantage of system expansion in this study is that it allows the consideration of existing benefits outside the studied system. This is required in order to fully account for the potential benefits of the chemicals produced in the kraft recovery system as co-products of the energy produced in that system.

Two allocation problems are encountered in life cycle of energy production using black liquor. First, the black liquor solids that are the primary raw material for producing the energy do not exist in isolation but rather are a co-product of kraft pulp production. In other words, the kraft pulping unit process is shared between the kraft pulp and the black liquor solids. Second, the kraft recovery system, in which the energy is produced, also generates chemicals that are reused within the kraft pulping process (i.e., the kraft recovery system is shared between the energy and the chemicals). The application of a system expansion approach to these allocation problems discussed below explains the final system boundary as will then be illustrated in Figure 2.7.

System Expansion for the Kraft Pulping Process

A simplified schematic of the kraft pulping allocation problem is illustrated in Figure 2.5. In order to apply system expansion to that allocation problem, it is necessary to determine which of the three following statements best describes the case of black liquor.

   1) Black liquor solids and kraft pulp are produced independently.
   2) The production of kraft pulp is dependent on the production of black liquor solids.
   3) The production of black liquor solids is dependent on the production of kraft pulp.

Statement #3 is the one which best describes the black liquor solids case. The production of both products (kraft pulp and black liquor solids) is determined by the demand for kraft pulp. Black liquor solids are produced because of that demand, and management actions chosen for black liquor solids will have little effect on the amount of pulp (and black liquor solids) produced. This is illustrated by the definition, for comparison purposes, of a parallel fossil fuel system in which kraft pulping remains constant (see Section 2.3.2 for more details). Using more black liquor solids for energy production will not affect the production of pulp. Instead, in theory[2], increased use of black liquor solids for energy results in less black liquor solids going to alternative management processes. For those specific situations, system expansion best practices (Ekvall and Weidema 2004) present two options:

   1) exclude the shared process from the system boundary of the product under investigation and subtract from it equivalent alternative management process; or
   2) exclude the shared process from the system boundary of the product under investigation and add an equivalent alternative management process to the system being compared.

Option 2 is used in this study because it gives systems that are more easily understood (see Section 2.3.2 for more details).

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[2] In practice, black liquor is always almost fully utilized for energy production.

National Council for Air and Stream Improvement

Raw Material

Kraft Pulping
(Shared Process)

Black Liquor
(used in the investigated
life cycle)

Kraft Pulp
(used in another
life cycle)
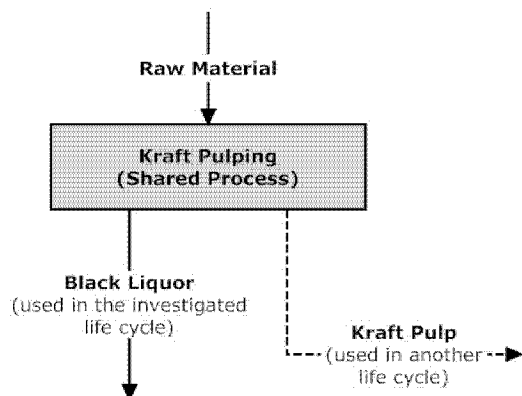
Figure 2.5 Kraft Pulping Allocation Problem

System Expansion for the Kraft Recovery System

A simplified schematic of this second allocation problem is shown in Figure 2.6a. Once again, it is necessary to determine which of the following statements best applies to the case of the energy.

    1) Energy and pulping chemicals are produced independently.
    2) The production of chemicals is dependent on the production of energy.
    3) The production of energy is dependent on the production of pulping chemicals.

Black liquor solids are burned in the recovery boiler to recover the inorganics in a suitable chemical form to regenerate the pulping chemicals and energy is produced at the same time. One could decide not to recover the energy and this would not have an effect on the regeneration of chemicals. At the same time, one could, in theory, decide to burn the black liquor solids for the energy and not to recover the chemicals. Therefore, Statement #1 is the one which best describes the kraft recovery system. In this case, best system expansion practices recommend subdividing the shared process into its individual components. In doing so, two subprocesses specific to each of the products (energy and pulping chemicals) are defined: the energy recovery subprocess (evaporation, concentration, burning in recovery boilers), and the chemical recovery subprocess (smelt dissolution, green liquor clarification, causticizing, lime reburning, white liquor clarification). The energy recovery process is now shared between the energy and the smelt that is used as a raw material for pulping chemical production. This is illustrated in Figure 2.6b. It is still necessary to determine which of the following statements best applies to the case of the energy.

    1) Energy and smelt are produced independently.
    2) The production of smelt is dependent on the production of energy.
    3) The production of energy is dependent on the production of smelt.
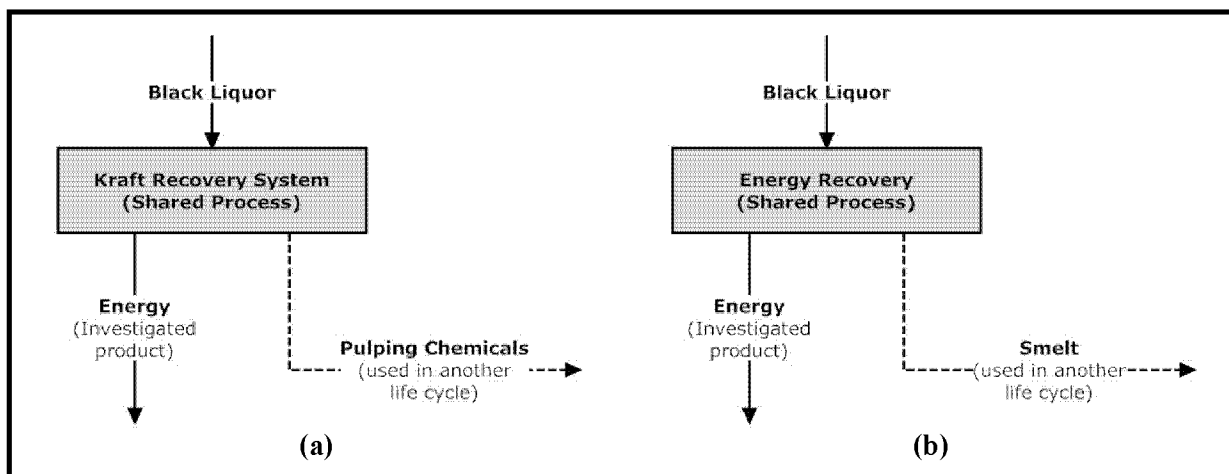
Figure 2.6 Kraft Recovery System Allocation Problem as Portrayed at
a) System Level, b) Energy Recovery Level

The production of smelt is now clearly dependent on the production of energy, which is the investigated product of this study. Reducing the combustion of black liquor solids that would otherwise be used to produce energy would reduce the production of smelt and pulping chemicals that would have to be produced otherwise. System expansion best practices for this situation are to include the shared process (energy recovery) in the system boundary and to include in the system boundary any other process that would be affected by a change in smelt production. This can be done by two different means:

1) expanding the system boundary to include the production of pulping chemicals using smelt and subtracting the alternative pulping production; or
2) expanding the system boundary to include the production of pulping chemicals using smelt and adding the alternative pulping chemical production to the compared system.

Option 2 is used in this study. The final system boundaries for the black liquor system are shown in Figure 2.7. The implications for the compared systems are discussed below.
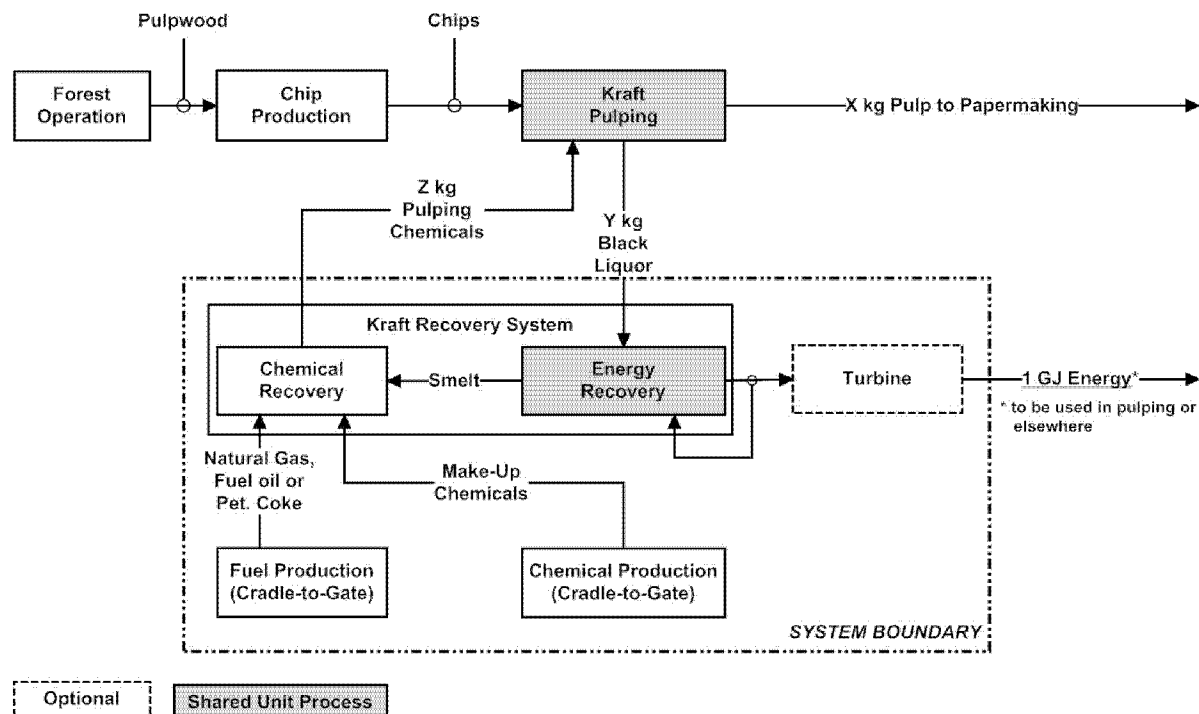
Figure 2.7 System Boundary for Energy Production Using Black Liquor Solids

Additional Functions

The primary functional unit of the system depicted in Figure 2.7 is the production of 1 GJ of energy. However, using the system expansion approach the investigated system has been expanded to include two secondary functions:

- the production of a fixed amount of pulping chemicals; and
- the management of black liquor solids.

2.3.1.3   *Summary of Processes Included and Excluded*

The system boundary includes the production and transportation of material (mainly make-up chemicals) and energy used in the kraft recovery process (mainly fuels for the lime kiln operations), as well as all other related upstream processes, the kraft recovery process itself and the turbine where applicable. It is assumed that the heat requirement for the kraft recovery system is satisfied internally. Capital equipment is not included.

2.3.2   *Fossil Fuel Product System*

To assess the potential benefits of the kraft recovery system, a parallel fossil fuel system has been defined. The ISO standard requires that in comparative studies "systems shall be compared using the same functional unit and equivalent methodological considerations [...]." For this reason, the fossil fuel system needs to encompass the same primary functional unit and the same two secondary functional units as the black liquor system:

- the production of 1 GJ of energy (in the same form as for the black liquor system);
- the production of a fixed amount of pulping chemicals; and
- the management of black liquor solids.

This is illustrated in Figure 2.8. The system boundary includes the extraction, processing, and transportation of fossil fuels prior to their conversion to energy, as well as the conversion processes themselves. The system boundary is expanded to include the alternative production of pulping chemicals and management of black liquor solids.
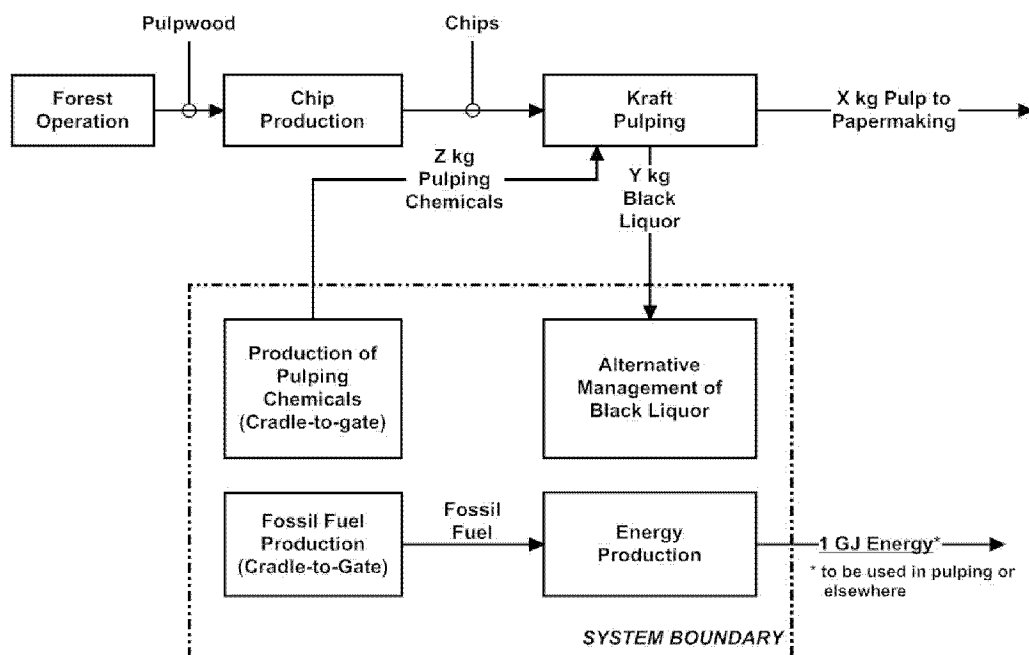
Figure 2.8 System Boundary for Energy Production Using Fossil Fuels

2.4   Impact Assessment and Other Indicators

Two indicators are characterized in this study: global warming, and life cycle non-renewable energy demand. More detail concerning these indicators is given in Table 2.1.

Table 2.1 Indicators Characterized

Indicator	Method	Unit	Description
Global warming	Intergovernmental Panel on Climate Change – 100 years (IPCC 2006)	kg CO_2 eq.	This indicator refers to the potential change in the earth's climate caused by the buildup of GHGs that trap heat radiated from the earth that would have otherwise passed out of the earth's atmosphere.
Life cycle non-renewable energy demand (NRE)	ecoinvent cumulative energy demand (Frischknecht et al. 2007; Goedkoop et al. 2008)	MJ	The objective of this indicator is to investigate the energy use throughout the life cycle of a good or service. This includes the direct uses as well as the indirect consumption of energy due to the use of, for example, construction materials or raw materials. The method includes renewable energy demand and non-renewable energy demand. Only the latter component is included in this study.

Net benefits are calculated as follows:

$$\text{Net GHG benefits (\%)} = \frac{\text{GHG}_{\text{Black liquor system}} - \text{GHG}_{\text{Fossil fuel system}}}{\text{GHG}_{\text{Fossil fuel system}}} \times 100$$

$$\text{Net resource benefits (\%)} = \frac{\text{NRE}_{\text{Black liquor system}} - \text{NRE}_{\text{Fossil fuel system}}}{\text{NRE}_{\text{Fossil fuel system}}} \times 100$$

2.5   Scenarios

Multiple scenarios are defined concerning 1) level of cogeneration from black liquor steam, 2) the fuel burned in lime kilns, 3) the heat energy displaced, and 4) the electricity displaced (see Table 2.2). The base case scenario (1.1, AI) assumes that all the steam produced from recovery boilers is sent to cogeneration turbines to produce electricity, that residual fuel oil is burned in lime kilns, that heat energy displaces energy from coal, and that cogenerated electricity displaces average electricity in the US (average grid). All scenarios are listed in Table 2.2. All possible combinations were analyzed, for a total of 36 scenarios.

Table 2.2 Scenarios Analyzed

Level of Cogeneration		Fuel Burned in Lime Kilns		Electricity		Heat Displaced	
1	Full	1	Residual fuel oil	A	Average US grid	I	Coal
2	None	2	Natural gas	B	Coal mix	II	Natural gas
		3	Petroleum coke	C	Natural gas combined cycle		

3.0 MODELING AND ASSUMPTIONS

3.1   Black Liquor System

3.1.1   *General Process Modeling*

A modular process simulation model using WinGEMS[3] was created to represent the material and energy flows in the digester, brown stock washing, recovery area, and steam and power system. The model simulates a bleached kraft pulp mill producing 1500 air-dried metric tonnes (admt) of bleached kraft pulp per day. A schematic of the full mill simulation is included in Appendix A. The sodium, potassium, sulfur, and chloride balance for the kraft pulping, oxygen delignification, and recovery areas is provided in Appendix B. The uncoated freesheet (UFS) results from the North American life cycle assessment report for printing and writing paper products served as the basis for tuning the base case simulation model for energy use and self-generated electricity amounts (NCASI 2010). There are 31 North American mills included in the UFS category in the North American life cycle assessment report. Of these 31 mills, energy inputs to 19 integrated[4] U.S. mills were used to tune the base case simulation model. The summary energy source information for the 19 US integrated mills producing primarily UFS product and the corresponding base case simulation fuel inputs and on-site electricity

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[3] WinGEMS is a process simulation program designed to model pulp and paper processes.
http://www.metso.com/automation/pp_prod.nsf/WebWID/WTB-050701-2256F-46EA1
[4] Integrated mills produce kraft pulp on site that is used to manufacture uncoated freesheet on site.

production amounts are given in Table 3.1. The major non-steam generating use of fuels is the energy requirements for lime kilns.

Based upon typical equipment operating conditions within the industry, the base case simulation model was used to quantify the material flows of cooking chemicals (NaOH and Na_2S), the steam and electricity generated by the black liquor recovery boiler and turbine system, and the energy consumed within the recovery area. Six simulation cases were constructed to provide cooking chemical material flow values and recovery area steam and electricity generation and consumption values for the life cycle modeling. The six simulation cases were divided into two subsets; one subset of the simulation model included cogeneration of electricity (i.e., a steam turbine generator system was integrated into the simulations), and one subset did not include cogeneration. The cases with and without cogenerated electricity were constructed to quantify the effects of cogenerated electricity on the life cycle results. Three simulation cases were constructed within the subsets by selecting different primary fuels in the lime kiln: residual fuel oil, natural gas, and petroleum coke. The three different lime kiln fuel simulations were constructed to provide complete coverage of the most common fuels used in lime kilns within the US pulp and paper industry.

Details of the key input parameters and output results for the simulation cases are provided in Appendix C.

Table 3.1 Production-Weighted Mean (PWM) Fuel Input and Electricity Production Values of 19 US Integrated Mills Producing Primarily Uncoated Freesheet Compared to Base Case Simulation Values

	PWM of UFS Mills		Base Case Simulation Values	
Black liquor solids fuel energy	18.55	GJ/admt	20.9	GJ/admt
Hogged fuel energy	6.39	GJ/admt	6.39	GJ/admt
Coal fuel energy	3.64	GJ/admt	3.64	GJ/admt
Natural gas fuel energy	4.02	GJ/admt	0.00	GJ/admt
Residual fuel oil	0.63	GJ/admt	1.78	GJ/admt
Total	33.2	GJ/admt	32.7	GJ/admt
Onsite electricity production	700	kWh/admt	703	kWh/admt

3.1.2 *Lime Kiln Fuel Energy*

The fuel mix for lime kilns operating at pulp and paper mills within the US, based on the NCASI combustion source database (NCASI 2005), is presented in Table 3.2.

Table 3.2 Fuel Mix for US Lime Kilns (NCASI 2005)

Fuel	Proportion in Mix[a] (%)
Natural gas	40.3
Residual fuel oil	56.4
Petroleum coke	3.3

[a] On an energy content basis.

The elemental composition, moisture content, and higher heating value (HHV) are required fuel specifications for the WinGEMS lime kiln model. Built-in fuel information for residual fuel oil and natural gas were adopted for the simulation and are presented in Table 3.3. Petroleum coke fuel

specifications were not available within the WinGEMS lime kiln model, and therefore literature value were used (Lee et al. 1997, 1999).

Table 3.3 Lime Kiln Fuel Specifications

Specification	Residual Fuel Oil	Natural Gas	Petroleum Coke
Carbon (wt. %)	85.8	74.8	86.3
Hydrogen (wt. %)	11	25.2	3.5
Nitrogen (wt. %)	-	-	1.6
Sulfur (wt. %)	3	-	5.5
Oxygen (wt. %)	0.45	-	0.5
Ash (wt. %)	0.05	-	0.3
Moisture (wt. %)	-	-	2.3
HHV (MJ/kg)	40.6	55.6	34.9

3.1.3 *Kraft Mill Steam Requirements*

Table 3.4 shows the department-level medium and low pressure steam requirements in the base case simulation model (residual fuel oil, with cogeneration). The small amount of high pressure steam used for recovery and power boiler sootblowing is not included in Table 3.4. Existing benchmarking results (Bruce 2000) indicate typical mill steam consumption values of between 17 GJ/admt for a 1990s vintage North American softwood bleached kraft mill to 22 GJ/admt for a 1980s vintage North American softwood bleached kraft mill.

Table 3.4 Department Medium and Low Pressure Steam Requirements—Base Case Simulation

Department	Steam Requirement (GJ/admt)
Medium pressure steam	
Digester	2.9
Oxygen delignification	1.7
Low pressure steam	
Pulp dryer	4.2
Evaporators	5.3
Steam stripper	1.5
Other[a]	2.4
Bleach plant	1.2
Digester	1.5
ClO_2 plant	0.2
Total medium and low pressure steam	20.9

[a] Other includes steam to deaerator, chiller, and other miscellaneous steam uses.

3.1.4 *Kraft Mill Electricity Requirements*

Steam and material flows were characterized within the simulation model. Kraft mill electricity requirements have been reviewed in a number of energy benchmarking studies involving hypothetical

model mills and data compiled from operating mills. The departmental electricity requirements from four studies are presented in Table 3.5. The "typical" 1990s North American mill in Bruce (2000) is based upon results from 1990s vintage operating mills. Other study results (Francis, Tower, and Browne 2002; Nygaard 1992) are based upon hypothetical model mills and would represent electricity consumption given best available technology.

Table 3.5 Departmental Electricity Requirements for Bleached Kraft Mills

Department[a]	Model Bleached Market Kraft Pulp Mill (Francis et al. 2002)	"Typical" 1990s North American Mill (Bruce 2000)	1980s US Mill (Nilsson et al. 1995)	1990 Model Mill (Nygaard 1992)
	(kWh/admt)			
Chip conveying	20	24	25	55
Digester	40	168	43	85
Washing and screening	30	-	103	-
Oxygen delignification	75	-	47	40
Bleaching[b]	100	124	42*	55
Screening and storage	-	-	74	45
Pulp machine	141	155	153	120
Black liquor evaporators	30	125	66	35
Steam stripping	-	-	-	-
Power plant	60	191	125	70
Kiln and recausticizing	50	30	42	60
Hot water supply	32	68	-	10
Wastewater treatment	30	-	-	30
Miscellaneous	30	-	61	20
Chemical preparation and oxygen	-	59	-	5
Total	638	944	781	630
Total – Kraft recovery only[c]	180	514	276	250

[a] Electricity consumption, mostly by pumping and air handling systems (Larson and Nilsson 1991), was not explicitly considered in the simulation model. Bleached kraft mill benchmarking studies from the literature were used to characterize the electricity requirements associated with the kraft recovery system, so these electricity requirements could be considered in the life cycle modeling.
[b] Three-stage bleaching.
[c] An average value was used in this study.

3.1.5 *Process Simulation Results*

The simulation results on a per air-dried metric tonne (admt) of bleached pulp and a per gigajoule
(GJ) of energy output are summarized in Table 3.6 and Table 3.7, respectively.

Table 3.6 Process Simulation Results (unit/admt of Bleached Pulp)

Material	Unit	Scenario					
		1.1	1.2	1.3	2.1	2.2	2.3
Inputs							
Black liquor solids	bdmt[a]	1.52	1.54	1.54	1.54	1.52	1.54
NaOH, 100%	kg	11.7	13.4	13.4	13.4	11.7	13.4
$Na_3H(SO_4)_2$ addition from R8/R10 plant	kg	18.6	16.3	16.2	16.3	18.6	16.2
Make-up lime (CaO)	kg	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162
Steam	GJ	6.80	6.80	5.50	5.40	5.70	5.90
Natural gas	GJ	1.90	0.00	0.00	1.78	0.00	0.00
Fuel oil	GJ	0.00	1.78	0.00	0.00	1.90	0.00
Petroleum coke	GJ	0.00	0.00	1.70	0.00	0.00	1.70
Electricity	GJ	0.834	0.834	0.834	0.834	0.834	0.834
Outputs							
Steam	GJ	14.5	14.4	14.4	16.1	16.1	16.1
Electricity	GJ	1.60	1.60	1.60	0.00	0.00	0.00
NaOH, 100%, to pulping	kg	328	332	333	333	328	333
Na_2S, to pulping	kg	114	124	124	124	114	124

[a] Bone dry metric tonne.

National Council for Air and Stream Improvement

Table 3.7 Process Simulation Results (unit/GJ of Net Energy Output)

Material	Unit	Scenario					
		1.1	1.2	1.3	2.1	2.2	2.3
Inputs							
Black liquor solids	bdmt[a]	0.178	0.182	0.158	0.143	0.148	0.151
NaOH, 100%	kg	0.00	0.00	0.00	0.00	0.00	0.00
$Na_3H(SO_4)_2$ addition from R8/R10 plant	kg	2.19	1.92	1.67	1.51	1.78	1.59
Make-up lime (CaO)	kg	0.00191	0.00191	0.00166	0.00150	0.00156	0.00162
Steam	GJ	0.00	0.00	0.00	0.00	0.00	0.00
Natural gas	GJ	0.223	0.00	0.00	0.650	0.00	0.00
Fuel oil	GJ	0.00	0.211	0.00	0.00	0.182	0.00
Petroleum coke	GJ	0.00	0.00	0.174	0.00	0.00	0.167
Electricity	kWh	0.00	0.00	0.00	0.00	0.00	0.00
Outputs							
Net energy output[b]	GJ	1.00	1.00	1.00	1.00	1.00	1.00
Steam	%	90.5	90.6	91.8	100	100	100
Electricity	%	9.50	9.40	8.20	0.00	0.00	0.00
NaOH, 100%, to pulping	kg	37.2	37.8	32.8	29.8	30.3	31.3
Na_2S, to pulping	kg	13.5	14.7	12.7	11.5	11.0	12.1

[a] Bone dry metric tonne.
[b] Energy output from which energy inputs have been subtracted.

3.1.6   *Chemicals and Fuels Used in Black Liquor System*

Chemicals and fuel consumed in the black liquor system were modeled based on data from a commercial life cycle inventory database (U.S. LCI). The datasets used are presented in Table 3.8.

Table 3.8 Data Sources for Chemicals and Fuels Used in Black Liquor System

Material	Database	Dataset
Natural gas	U.S. LCI	Natural gas, combusted in industrial equipment/RNA
Fuel oil	U.S. LCI	Residual fuel oil, combusted in industrial boiler/US
Petroleum coke	U.S. LCI	Petroleum coke, at refinery/kg/US, CO_2 combustion emissions from NCASI
Make-up lime	U.S. LCI	Quicklime, at plant/US

NOTE: RNA=North America.

3.2 Fossil Fuel System

3.2.1 General Modeling Assumptions

The fossil fuel system has been modeled using data from commercially available databases (U.S. LCI, ecoinvent). These databases include energy production efficiencies. For electricity, it was assumed that transmission losses were 7% of the produced power (U.S. Energy Information Agency 2010). Datasets used are presented in Table 3.9.

Table 3.9 Data Sets Used for the Fossil Fuel System

Energy type	Database	Dataset
Heat from coal	U.S. LCI	Bituminous coal, combusted in industrial boiler/US
Heat from natural gas	U.S. LCI	Natural gas, combusted in industrial boiler/US
Average U.S. electricity	U.S. LCI/ecoinvent	Based on 2006 fuel mix: Electricity, coal mix, at power plant/US (U.S. LCI); Electricity, residual fuel oil, at power plant/US (U.S. LCI); Electricity, natural gas, at power plant/US (U.S. LCI); Electricity, nuclear, at power plant/US (U.S. LCI); Electricity, hydropower, at power plant/SE (ecoinvent); Electricity, at wind power plant 800kW/RER (ecoinvent); Electricity, production mix photovoltaic, at plant/US (ecoinvent); Electricity, biomass, at power plant/US (U.S. LCI); No data for geothermal
Coal-based electricity	U.S. LCI	Electricity, coal mix, at power plant/US
Electricity from natural gas combined cycle	ecoinvent	Natural gas, burned in gas turbine/DE

NOTES: SE=Sweden, DE=Germany.

3.2.2 Alternative Chemical Production

The recovery of black liquor solids results in the production of two essential chemicals for the pulping process: sodium hydroxide (NaOH) ("caustic") and sodium sulfide (Na_2S). To make the fossil fuel system equivalent to the black liquor system, it is necessary to include an equivalent alternative chemical production in the fossil fuel system.

Life cycle data for caustic production are from the U.S. LCI database (see Table 3.10).

No life cycle data are available for sodium sulfide production. For this reason, a data set was constructed. Industrially, sodium sulfide can be produced through several different process pathways. In this study, it was assumed that sodium sulfide is produced by the reduction of sodium sulfate (Na_2SO_4) with carbon (charcoal). This process pathway was selected because it already takes place in pulp and paper mills given that sodium sulfate is often used as a make-up chemical. Resource and energy requirements were estimated from stoichiometry and heat of reaction:

$$Na_2SO_4 + 4C \xrightarrow{H_R=-12966\ kJ/kg} Na_2S + 4CO$$
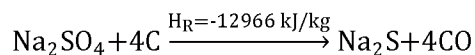
Also, since this reaction occurs at high temperatures (900°C-1000°C), an additional energy requirement (2215 kJ/kg Na_2S) for bringing the reactants to the appropriate temperature was included. The energy was assumed to be provided by natural gas. Natural gas life cycle information was obtained from the U.S. LCI database while sodium sulfate and charcoal life cycle information was obtained from the ecoinvent database (see Table 3.10).

There are several process pathways to produce sodium sulfide, but it is unlikely that the choice of pathway has a significant impact on energy requirements. For instance, in contrast to the pathway selected above, a different pathway involves the saturation of a caustic soda solution with hydrogen sulfide (H_2S) and further reaction with caustic. This pathway has an enthalpy of reaction very similar to the previous one. It does not require as high a temperature but the solution produced with caustic and sodium sulfide needs to be concentrated before further reaction. Furthermore, the life cycle GHG emissions associated with the chemicals used in this latter pathway are similar to those in the previous pathway.

Table 3.10 Data Sources for Alternative Chemical Production

Material	Database	Dataset
Caustic	U.S. LCI	Sodium hydroxide, production mix, at plant/kg/RNA
Sodium sulfate	ecoinvent	Sodium sulphate, powder, production mix, at plant/RER
Carbon	ecoinvent	Charcoal, at plant/GLO, assuming charcoal is 95% carbon
Natural gas	U.S. LCI	Natural gas, combusted in industrial equipment/RNA

NOTES: RNA= North America, RER=average Europe, GLO=global.

3.2.3 *Alternative Management of Black Liquor Solids*

The recovery of black liquor not only provides energy and chemicals for the pulp and paper process, it also allows disposing of the organic matter. For this reason, to make the fossil fuel- and black liquor-based kraft recovery systems equivalent, it is necessary to include an equivalent management of black liquor solids in the fossil fuel-based system.

A detailed model of alternative management of black liquor solids would have required too much speculation, but the management would almost certainly ultimately involve returning the biogenic carbon in the liquor to the atmosphere. In the best case, it would return as CO_2, so this is what has been modeled. The alternative management may involve greater emissions of GHGs if, for instance, some the biogenic carbon is returned to the atmosphere as methane or if fossil fuels were required. For this reason, the approach taken is conservative.

3.3 Other Supporting Information

3.3.1 *Transportation*

Data to estimate emissions related to transportation of materials are based on the U.S. LCI database where available or estimated from the 2002 U.S. Commodity Flow Survey (U.S. Department of Transportation and U.S. Department of Commerce 2004, Table 6), (http://www.census.gov/svsd/www/cfsdat/2002cfs-us.html)[5]. One-way trips were assumed. More information can be found in Table 3.11 and Table 3.12. Transportation processes were modeled using the U.S. LCI and ecoinvent databases (see Table 3.13).

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[5] Neglecting multimodal transportation.

Table 3.11 Transportation Distances and Modes Based on US LCI Database

Material	Unit	Truck	Rail	Water, Inland	Pipeline
		tkm/unit	tkm/unit	tkm/unit	tkm/unit
Natural gas	m^3	0.199	0.0119	-	1.19
Fuel oil	L	0.00525	0.00336	0.0284	-
Petroleum coke	kg	0.0290	0.676	0.0470	-
Bituminous coal	kg	0.00676	1.04	-	0.00502

Table 3.12 Transportation Distances and Modes Based on Commodity Flow

SCGT 3-Digit Category	Used for	Truck		Rail		Water, Inland	
		%	Distance (km)	%	Distance (km)	%	Distance (km)
Sodium hydroxide (caustic soda) and potassium hydroxide (caustic potash)	NaOH	41.3	230	39.7%	927	19.0%	776
Inorganic chemicals	CaO, Na_2S, sodium sulfate	73.7%	183	21.9%	1088	4.3%	489
Other wood product	Charcoal	100%	303	-	-	-	-

Table 3.13 Data Sets for Transportation Processes

Transportation Process	Database	Dataset
Truck	U.S. LCI	Transport, combination truck, average fuel mix/US
Rail	U.S. LCI	Transport, train, diesel powered/US
Water, inland	U.S. LCI	Transport, barge, average fuel mix/US
Pipeline	ecoinvent	Transport, natural gas, pipeline, long distance/RER Transport, crude oil pipeline, onshore/RER

3.3.2 *Heat Contents*

The process simulation produced energy balances in energy units while some U.S. LCI database combustion data are in mass units. Hence, heating values presented in Table 3.14 were used.

Table 3.14 Fuel Heating Values

Fuel	Unit	Heating Value (GJ LHV[a]/unit)
Natural gas	m^3	0.0351
Fuel oil	L	0.0420
Coal	kg	0.0295

[a] 1 GJ HHV $\approx$ 0.95 GJ LHV.

4.0 RESULTS

The main GHG mitigation benefits results are presented in Table 4.1. The results for the individual scenarios can be found in Appendix B.

These results show that for the base case scenario (full cogeneration, natural gas burned in the kilns, average US grid displaced, and heat from coal displaced), the recovery of black liquor produced a reduction of approximately 182 kg CO_2 eq./GJ, or 91% of fossil fuel CO_2.

When combining all scenarios, a median reduction of approximately 140 kg CO_2 eq./GJ, or 90% of fossil fuel CO_2, is estimated. When no cogeneration is considered about 90% of the benefit is reached. Finally, the benefits from the recovery of the chemicals vary from 44% to 75% of the total benefit.

Table 4.1 Summary of GHG Mitigation Benefits Results

Scenario/Case	Absolute Reduction (kg CO_2 eq./GJ)	Relative Reduction (%)	Contribution of Chemical Recovery (%)
Base case (1.1, AI)	182	90.5%	49.8%
Min	97.9	69.0%	74.9%
Median	142	88.0% (89.9%, 79.9%)[a]	54.3%
Max	192	92.4%	44.2%

[a] (with cogeneration, without cogeneration).

Table 4.2 frames the GHG emission reduction due to black liquor recovery in the context of the emissions of the entire US forest products industry. It shows that the reduction is essentially enough to fully offset Scope 1 (direct) and Scope 2 (purchased electricity) emissions.

Table 4.2 US Total GHG Emissions Reduction Due to Use of Black Liquor Solids

Energy from black liquor solids in US in 2004	1.05e09 GJ (Heath et al. 2010)
Total potential GHG reduction due to black liquor recovery	149 Tg CO_2 eq.[a]
Scope 1 & 2 GHG emissions (fossil) by the whole US forest products manufacturing facilities in 2004	108 Tg CO_2 (Heath et al. 2010)

[a] Calculated: 142 kg CO_2 eq./GJ x 1.05E09 GJ = 1.49E11 kg CO_2 eq. = 149 Tg CO_2 eq.

The main non-renewable energy consumption benefits results are presented in Table 4.3. The results for the individual scenarios can be found in Appendix E.

Table 4.3 Summary of Non-Renewable Energy Conservation Benefits Results

Scenario/Case	Absolute Reduction (GJ_{NR}/GJ)[a]	Relative Reduction (%)	Contribution of Chemical Recovery (%)
Base case (1.1, AI)	2.51	89.8%	55.2%
Min	1.49	71.1%	68.4%
Median	1.91	87.1% (89.2%, 77.0%)[b]	55.4%
Max	2.51	90.7%	47.0%

[a] GJ_{NR}: Life cycle non-renewable energy required to produce 1 GJ of energy.
[b] (with cogeneration, without cogeneration).

These results show that for the base case scenario (full cogeneration, natural gas burned at the kilns, average US grid displaced, and heat from coal displaced) , the recovery of black liquor solids produced a reduction of approximately 2.51 GJ non-renewable energy for each GJ of energy output (90% reduction). When considering all scenarios, a median reduction of approximately 1.91 GJ/GJ is achieved. When no cogeneration is considered, about 90% of the benefit is reached. The benefits from recovery of the pulping chemicals vary from 47% to 68% of the total benefit.

5.0 LIMITATIONS

The intent of this study was to improve the understanding of the GHG mitigation and fossil fuel conservation benefits of black liquor solids recovery. It is important to understand the limitations of the study before drawing conclusions. The main limitations of the study are the following:

- the use of assumptions regarding the types of energy displaced, and particularly the nature of the alternative chemical production processes, introduces uncertainty;

- the completeness and applicability of some of the inventory data used are open to question especially regarding:

    o   the modeling of the production of sodium sulfide; and

    o   the use of some secondary data from European LCI database (ecoinvent);

- the limited scope of the life cycle impact assessment precludes a comprehensive view of the life cycle impacts; and

- because LCIA indicator results are relative expressions they cannot be used to predict impacts on category endpoints, exceedances of thresholds, safety margins, or risk.

6.0 CONCLUSIONS

In this study, the life cycle GHG and fossil fuel-related benefits of black liquor solids recovery were analyzed. These benefits are due to two effects: the production of energy that can be used in the pulping process or sold, and the recovery of the pulping chemicals that would otherwise need to be produced from other resources.

The fossil GHG emissions and non-renewable energy consumption for a system using black liquor solids in the kraft recovery system are approximately 90% lower than those for a comparable fossil fuel-based system. When applying this reduction to the production of kraft pulp in the US, the avoided emissions are enough to offset all of the total Scope 1 and Scope 2 emissions from the entire US pulp and paper industry (all mills). This result does not depend on the accounting method for biogenic carbon because biogenic CO_2 emissions are the same for the systems compared and the result is valid across a range of assumptions about the displaced fossil fuel, the GHG intensity of the electricity grid, the fossil fuels used in the lime kiln, and the level of cogeneration at pulp and paper mills. The benefits occur without affecting the amount of wood harvested or the amount of chemical pulp produced.

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APPENDIX A

SCHEMATIC OF THE FULL MILL SIMULATION
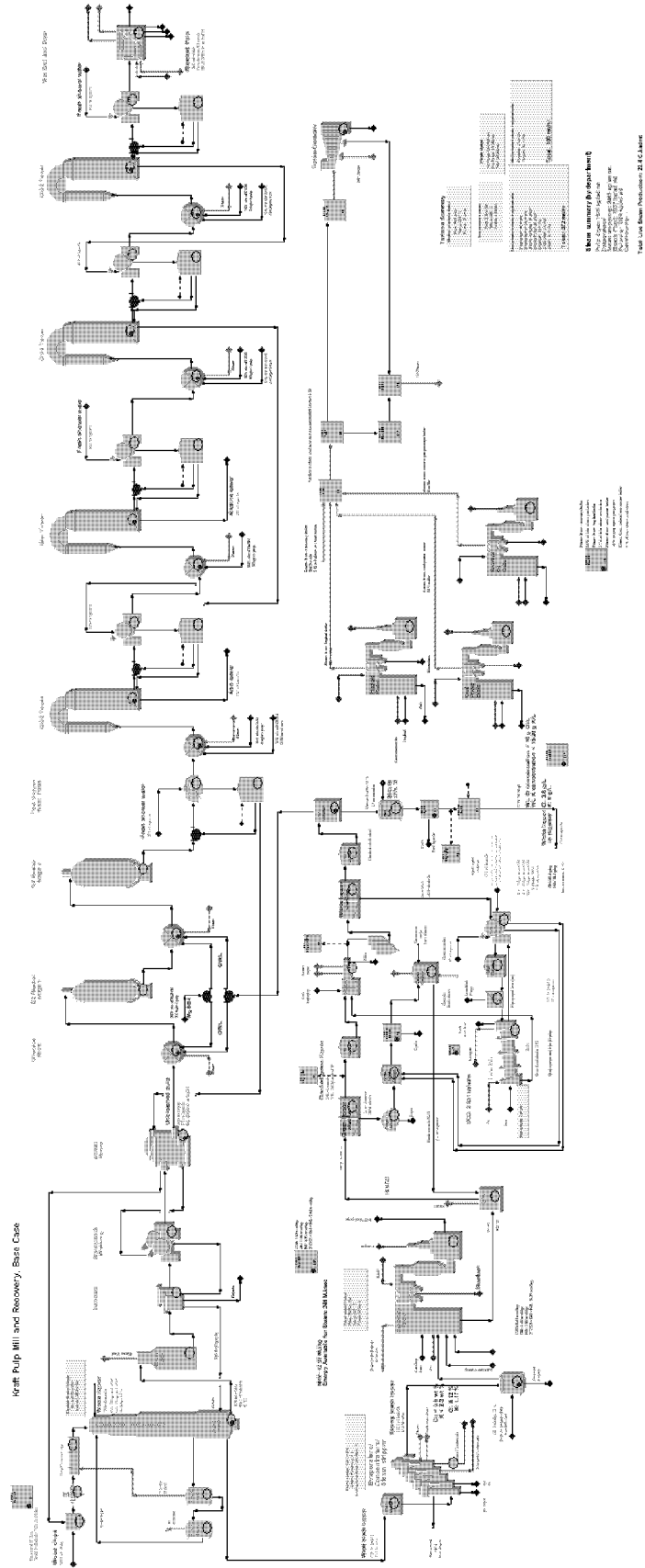
APPENDIX B

SODIUM, POTASSIUM, SULFUR, AND CHLORIDE BALANCE FOR THE KRAFT PULPING, OXYGEN DELIGNIFICATION AND RECOVERY AREA

Material	Production (1500 admt/day)			
	Na	K	S	Cl
	kg/admt	kg/admt	kg/admt	kg/admt
Input				
Raw material	0.11	1.17	0.19	0.69
Caustic make-up	7.73	-	-	-
$Na_3H(SO_4)_2$ from R8/R10	4.89	-	4.55	-
Kiln Oil	-	-	2.68	-
O_2 $MgSO_4$	-	-	0.95	-
Total	12.73	1.174	8.38	0.69
Output				
Wash losses to bleach plant	2.10	0.41	0.68	0.00
Accidental black liquor losses	2.79	0.18	0.62	0.11
Accidental white liquor losses	2.14	0.13	0.52	0.08
Dregs and grits	0.51	0.03	0.12	0.02
Purged ESP dust	3.60	0.36	2.22	0.42
Recovery boiler flue gas	0.43	0.04	0.26	0.05
Purged lime dust	0.35	0.00	0.24	0.00
Knotter rejects	0.21	0.02	0.06	0.01
Sewered neutralized spent acid	0.62	0.00	0.58	0.00
Evaporator foul condensates	-	-	0.43	-
Evaporator NCG	-	-	0.38	-
Digester flash steam scrubber	-	-	0.87	-
Kiln flue gas	-	-	1.42	-
Total	12.73	1.175	8.40	0.69

APPENDIX C

KEY INPUT PARAMETERS AND OUTPUT RESULTS FOR THE SIMULATION CASES

Key Output Values	Co-generation cases			Non co-generation cases			Units
	Kiln fired with…			Kiln fired with…			
	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	
Bleached Pulp							
Production rate	1500	1500	1500	1500	1500	1500	admt/day (10% moisture)
Production rate	1425	1425	1425	1425	1425	1425	machine dried mt/day (5% water)
Unbleached Pulp							
Production rate	1562	1562	1562	1562	1562	1562	admt/day
Fresh shower water to O_2 wash press	475	475	475	475	475	475	mt/hr
O_2 wash press dilution factor	5.8	5.8	5.8	5.8	5.8	5.8	-
O_2 wash press wash liquor ratio	3.5	3.5	3.5	3.5	3.5	3.5	-
Sodium losses from brown stock	2.2	2.2	2.2	2.2	2.2	2.2	kg Na/admt pulp
White Liquor							
Flow rate	175	171	175	175	171	175	mt/hr
Temperature	101	101	101	101	101	101	°C
EA	130	131	130	130	131	130	g/L as NaOH
Sulfidity	32.0	30.3	32.0	32.0	30.3	32.0	%
Carbonate (as Na_2CO_3)	26	27	26	26	27	26	g/L
Caustic make-up (50% NaOH solution)	1.7	1.5	1.7	1.7	1.5	1.7	mt/hr
Mass flow of hydroxide in white liquor	20.8	20.5	20.8	20.8	20.5	20.8	mt/hr as (100% NaOH)
Mass flow of hydrosulfide in white liquor	7.7	7.1	7.7	7.7	7.1	7.7	mt/hr as (100% Na_2S)

C2

Key Output Values	Co-generation cases Kiln fired with…			Non co-generation cases Kiln fired with…			Units
	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	
Oxidized White Liquor							
Flow rate	9.4	9.3	9.4	9.4	9.3	9.4	mt/hr
EA	119	121	119	119	121	119	g/L as NaOH
Mass flow of hydroxide in oxidized white liquor	1.02	1.02	1.02	1.02	1.02	1.02	mt/hr as (100% NaOH)
Digester							
Circulation heaters steam flow	63	63	63	63	63	63	mt/hr
Wash liquor heater steam flow	35	35	35	35	35	35	mt/hr
Evaporators/Concentrators							
Weak black liquor flow	734	730	734	735	730	735	mt/hr
Weak black liquor total dissolved solid content	13.1	13.0	13.1	13.1	13.0	13.1	mass %
Weak black liquor total inorganic load (% of TDS)	28.3	27.7	28.4	28.3	27.7	28.4	mass %
Strong black liquor total dissolved solids	67.4	67.4	67.4	67.4	67.4	67.4	mass %
Steam flow	120	119	120	120	120	120	mt/hr
Steam economy	4.9	4.9	4.9	4.9	4.9	4.9	
Boiling point rise of strong black liquor	13	13	13	13	13	13	Δ°C
Tall oil	2.4	2.4	2.4	2.4	2.4	2.4	mt/hr
Recovery Boiler							
Superheated steam flow leaving boiler	308	309	308	308	309	308	mt/hr
Temperature of superheated steam	450	450	450	450	450	450	°C
Pressure of superheated steam	85	85	85	85	85	85	bars
Enthalpy of superheat steam	3264	3264	3264	3264	3264	3264	kJ/kg

Key Output Values	Co-generation cases Kiln fired with…			Non co-generation cases Kiln fired with…			Units
	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	
Energy content of superheated steam leaving boiler	16.1	16.1	16.1	16.1	16.1	16.1	GJ/admt
High pressure steam used for sootblowing	7.9	7.9	7.9	7.9	7.9	7.9	mt/hr
High pressure steam used for sootblowing	2.50	2.50	2.50	2.50	2.50	2.50	% of total recovery boiler steam
Calculated black liquor HHV	12.97	13.07	12.97	12.97	13.07	12.97	MJ/kg solids
As-fired black liquor flow rate	100.6	99.1	100.7	100.6	99.1	100.7	mt solids/hr
As-fired liquor dry solids	1.61	1.59	1.61	1.61	1.59	1.61	kg dry solids/admt pulp
Black liquor fuel energy	20.9	20.7	20.9	20.9	20.7	20.9	GJ/admt
Black liquor elemental composition							
C	34.8	35.3	34.8	34.8	35.3	34.8	wt % solids
H	4.0	4.0	4.0	4.0	4.0	4.0	wt % solids
S	5.5	5.2	5.6	5.5	5.2	5.6	wt % solids
Na	19.8	19.5	19.8	19.8	19.5	19.8	wt % solids
O	33.6	33.7	33.6	33.6	33.7	33.6	wt % solids
K	1.3	1.3	1.3	1.3	1.3	1.3	wt % solids
Cl	0.9	1.0	0.9	0.9	1.0	0.9	wt % solids
$Na_3H(SO_4)_2$ addition from R8/R10 plant	1.02	1.16	1.02	1.02	1.16	1.01	mt/hr
Auxiliary Fuel[1]	0.00	0.00	0.00	0.00	0.00	0.00	mt/hr
Power Boiler							
Hogged fuel flow (including hogged fuel water content)[3]	38.96	38.96	38.96	36.95	36.36	36.96	mt/hr
Moisture content of hogged fuel	0.50	0.50	0.50	0.50	0.50	0.50	mass fraction
Hogged fuel energy	6.39	6.39	6.39	6.06	5.96	6.06	GJ/admt
Steam production from hogged fuel boiler	102.1	102.1	102.1	96.8	95.3	96.8	mt/hr

Key Output Values	Co-generation cases			Non co-generation cases			Units
	Kiln fired with…			Kiln fired with…			
	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	
Steam production from hogged fuel boiler	21.3	21.3	21.3	23.9	23.6	23.9	% of total steam production
Coal flow to power boiler[4]	7.4	7.4	7.4	0.0	0.0	0.0	mt/hr
Coal fuel energy	3.64	3.64	3.64	0.00	0.00	0.00	GJ/admt
Steam production from coal power boiler	68.1	68.1	68.1	0.0	0.0	0.0	mt/hr
Steam production from coal power boiler	14.2	14.2	14.2	0.0	0.0	0.0	% of total steam production
Natural gas flow to power boiler[5]	0.0	0.0	0.0	0.0	0.0	0.0	mt/hr
Natural gas fuel energy	0.0	0.0	0.0	0.0	0.0	0.0	GJ/admt
Steam production from natural gas power boiler	0.0	0.0	0.0	0.0	0.0	0.0	mt/hr
Steam production from natural gas power boiler	0.0	0.0	0.0	0.0	0.0	0.0	% of total steam production
Smelt Dissolving Tank							
Smelt flow rate	39	38	39	39	38	39	mt/hr
Steam flow rate	4.9	4.8	4.9	4.9	4.8	4.9	mt/hr
(2*EA - AA)/(TTA + 2EA - 2AA)*100	18.9	19.3	19.0	18.9	19.3	19.0	%
Clarified Green Liquor							
Flow rate	249	245	249	249	245	249	mt/hr
Temperature	100	100	100	100	100	100	°C
Green liquor $CO_3^=$ concentration	66.1	67.3	66.0	66.1	67.3	66.0	g/L
Green liquor OH^- concentration	19.1	18.9	19.1	19.1	18.9	19.0	g/L
Slaking/Causticizing							
Steam flow rate	8.8	8.8	8.8	8.8	8.8	8.8	mt/hr
(2*EA - AA)/(TTA + 2EA - 2AA)*100	82.4	82.5	82.4	82.4	82.5	82.4	%
Fresh water to liquor preparation	190	187	190	190	187	190	mt/hr

Key Output Values	Co-generation cases Kiln fired with…			Non co-generation cases Kiln fired with…			Units
	Fuel oil²	Natural Gas⁵	Petcoke⁷	Fuel oil²	Natural Gas⁵	Petcoke⁷	
Lime make-up	0.001	0.001	0.001	0.001	0.001	0.001	mt/hr
Lime Mud							
Flow rate	74	75	75	74	75	75	mt/hr
Lime Kiln							
Fuel usage	2.70	2.11	3.00	2.70	2.11	3.00	mt/hr
Energy consumption per weight of product	6.80	7.24	6.42	6.80	7.24	6.42	GJ/mt
Energy consumption per weight of lime	8.09	8.62	7.72	8.09	8.62	7.72	GJ/mt
Energy consumption per admt of bleached pulp	1.78	1.90	1.70	1.78	1.90	1.70	GJ/admt
Energy Summary							
Medium pressure steam flow from turbines	100	99	100	0	0	0	mt/hr
Temperature	223.6	223.6	223.6	0.0	0.0	0.0	°C
Pressure	12.0	12.0	12.0	0.0	0.0	0.0	bar
Enthalpy	2871.9	2871.9	2871.9	2872.6	2872.6	2872.6	kJ/kg
Low pressure steam flow from turbines	213	214	213	0	0	0	mt/hr
Temperature	147.9	147.9	147.9	0.0	0.0	0.0	°C
Pressure	4.5	4.5	4.5	0.0	0.0	0.0	bar
Enthalpy	2741.0	2741.0	2741.0	2786.7	2786.7	2786.7	kJ/kg
Medium pressure steam requirements							
Digester	63	63	63	63	63	63	mt/hr
Oxygen delignification	36	36	36	37	37	37	mt/hr
Low pressure steam requirements							
Pulp dryer	95	95	95	95	95	95	mt/hr
Evaporators	120	119	120	120	120	120	mt/hr

Key Output Values	Co-generation cases Kiln fired with...			Non co-generation cases Kiln fired with...			Units
	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	
Steam stripper	35	35	35	35	35	35	mt/hr
Other[6]	55	55	55	55	55	55	mt/hr
Bleach plant	28	28	28	28	28	28	mt/hr
Digester	35	35	35	35	35	35	mt/hr
ClO$_2$ plant	3.9	3.9	3.9	3.9	3.9	3.9	mt/hr
Total steam consumption	20.9	20.9	20.9	21.2	21.2	21.2	GJ/admt
Turbine condensate	2.9	2.9	2.9	0.0	0.0	0.0	mt/hr
Power Production							
1st turbine stage	34.4	34.4	34.4	0.0	0.0	0.0	MW
MP steam extraction	99.5	99.2	99.5	0.0	0.0	0.0	mt/hr
2nd turbine stage	9.6	9.6	9.6	0.0	0.0	0.0	MW
MP steam extraction	213.4	214.0	213.4	0.0	0.0	0.0	mt/hr
Total	44.0	44.0	44.0	0.0	0.0	0.0	MW
Fraction of high pressure steam not passing through turbine	0.34	0.34	0.34	1.00	1.00	1.00	
High pressure turbine steam from recovery boiler	203.5	203.8	203.5	0.0	0.0	0.0	mt/hr
High pressure turbine steam from hogged fuel boiler	67.4	67.4	67.4	0.0	0.0	0.0	mt/hr
High pressure turbine steam from coal power boiler	45.0	45.0	45.0	0.0	0.0	0.0	mt/hr
High pressure turbine steam from natural gas power boiler	0.0	0.0	0.0	0.0	0.0	0.0	mt/hr
Produced electricity-to-heat ratio	33.6	33.8	33.6	0.0	0.0	0.0	KWh of power produced/GJ steam produced

| Key Output Values | Co-generation cases | | | Non co-generation cases | | | Units |
| | Kiln fired with… | | | Kiln fired with… | | | |
	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	Fuel oil[2]	Natural Gas[5]	Petcoke[7]	
Turbine electricity-to-heat ratio	51.0	51.2	51.0	0.0	0.0	0.0	kWh of power produced/GJ HP steam to turbine
Electricity production	703	704	703	0.0	0.0	0.0	kWh of power produced/admt

[1] No. 2 Fuel Oil: C - 87.3%, H - 12.6%, S - 0.22%, O - 0.04 %, Ash - < 0.01%, HHV - 44.7 MJ/kg; [2] No. 6 High Sulfur Fuel Oil: C - 85.5%, H - 11%, S - 3%, O - 0.45 %, Ash - 0.05%, HHV - 40.6 MJ/kg; [3] Dry Hogged fuel: C - 51.5%, H - 6.1%, S - 0.1%, O - 41.1 %, Ash - 1.1%, N - 0.1 %, HHV - 20.5 MJ/kg; [4] Coal: C - 76.2%, H - 5.1%, S - 1.5%, O - 6.7%, Ash - 8.9%, N - 1.6 %, HHV - 32.2 MJ/kg; [5] Natural gas: C - 74.8%, H - 25.2%, HHV - 55.6 MJ/kg; [6] Other includes steam to deaerator, chiller, and other misc. steam uses; [7] Petcoke: C - 86.3%, H 3.5%, S 5.5%, O 0.5%, Ash 0.3%, HHV 34.9 MJ/kg

APPENDIX D

GHG MITIGATION BENEFITS—FULL RESULTS

Scenario	Black Liquor System	Fossil Fuel System	Difference		Chemical Contribution	
	(kg CO_2 eq./GJ, %)					
1.1, AI	19.1	201	-182	-90.5%	-90.4	49.8%
1.1, AII	15.7	169	-154	-90.7%	-86.1	56.1%
1.1, BI	15.7	207	-191	-92.4%	-86.1	45.0%
1.1, BII	15.7	180	-164	-91.3%	-86.1	52.4%
1.1, CI	15.7	183	-167	-91.4%	-86.1	51.6%
1.1, CII	15.7	156	-140	-89.9%	-86.1	61.6%
1.2, AI	15.7	196	-181	-92.0%	-86.1	47.7%
1.2, AII	19.1	174	-155	-89.0%	-90.4	58.5%
1.2, BI	19.1	211	-192	-91.0%	-90.4	47.0%
1.2, BII	19.1	184	-165	-89.7%	-90.4	54.7%
1.2, CI	19.1	187	-168	-89.8%	-90.4	53.9%
1.2, CII	19.1	160	-141	-88.1%	-90.4	64.2%
1.3, AI	19.3	187	-168	-89.7%	-78.2	46.6%
1.3, AII	19.3	160	-140	-87.9%	-78.2	55.7%
1.3, BI	19.3	196	-177	-90.2%	-78.2	44.2%
1.3, BII	19.3	169	-150	-88.6%	-78.2	52.3%
1.3, CI	19.3	175	-156	-89.0%	-78.2	50.2%
1.3, CII	19.3	148	-128	-86.9%	-78.2	60.9%
2.1, AI	33.2	170	-137	-80.5%	-70.2	51.3%
2.1, AII	27.9	141	-113	-80.2%	-71.0	62.8%
2.1, BI	36.8	171	-134	-78.5%	-71.0	53.0%
2.1, BII	36.8	141	-104	-73.9%	-71.0	68.1%
2.1, CI	16.6	171	-154	-90.3%	-71.0	46.0%
2.1, CII	16.6	141	-124	-88.3%	-71.0	57.1%
2.2, AI	27.9	171	-143	-83.7%	-71.0	49.7%
2.2, AII	33.2	140	-107	-76.3%	-70.2	65.6%
2.2, BI	42.3	170	-128	-75.1%	-70.2	55.0%
2.2, BII	42.3	140	-98	-69.8%	-70.2	71.7%
2.2, CI	21.5	170	-149	-87.3%	-70.2	47.3%
2.2, CII	21.5	140	-119	-84.7%	-70.2	59.2%
2.3, AI	35.6	175	-139	-79.6%	-74.8	53.8%
2.3, AII	35.6	145	-109	-75.4%	-74.8	68.5%
2.3, BI	44.9	175	-130	-74.3%	-74.8	57.7%
2.3, BII	44.9	145	-100	-69.0%	-74.8	74.9%
2.3, CI	23.7	175	-151	-86.5%	-74.8	49.5%
2.3, CII	23.7	145	-121	-83.7%	-74.8	61.7%

APPENDIX E

NON-RENEWABLE ENERGY BENEFITS—FULL RESULTS

Scenario	Black Liquor System	Fossil Fuel System	Difference		Chemical Contribution	
	(GJ$_{NR}$/GJ, %)					
1.1, AI	0.257	2.51	-2.25	-89.8%	-1.24	55.2%
1.1, AII	0.275	2.58	-2.31	-89.3%	-1.19	51.5%
1.1, BI	0.275	2.58	-2.30	-89.3%	-1.19	51.5%
1.1, BII	0.275	2.71	-2.43	-89.8%	-1.19	48.8%
1.1, CI	0.275	2.28	-2.01	-88.0%	-1.19	59.1%
1.1, CII	0.275	2.41	-2.14	-88.6%	-1.19	55.5%
1.2, AI	0.275	2.45	-2.18	-88.8%	-1.19	54.5%
1.2, AII	0.257	2.64	-2.38	-90.3%	-1.24	52.2%
1.2, BI	0.257	2.63	-2.38	-90.3%	-1.24	52.2%
1.2, BII	0.257	2.76	-2.51	-90.7%	-1.24	49.5%
1.2, CI	0.257	2.34	-2.08	-89.0%	-1.24	59.7%
1.2, CII	0.257	2.47	-2.21	-89.6%	-1.24	56.2%
1.3, AI	0.271	2.31	-2.04	-88.3%	-1.07	52.5%
1.3, AII	0.271	2.45	-2.18	-88.9%	-1.07	49.4%
1.3, BI	0.271	2.42	-2.15	-88.8%	-1.07	49.9%
1.3, BII	0.271	2.56	-2.29	-89.4%	-1.07	47.0%
1.3, CI	0.271	2.17	-1.90	-87.5%	-1.07	56.6%
1.3, CII	0.271	2.30	-2.03	-88.2%	-1.07	52.9%
2.1, AI	0.435	2.05	-1.62	-78.8%	-0.97	59.7%
2.1, AII	0.435	2.21	-1.77	-80.3%	-0.98	55.1%
2.1, BI	0.539	2.06	-1.52	-73.9%	-0.98	64.0%
2.1, BII	0.539	2.21	-1.67	-75.6%	-0.98	58.5%
2.1, CI	0.296	2.06	-1.77	-85.7%	-0.98	55.2%
2.1, CII	0.296	2.21	-1.91	-86.6%	-0.98	51.0%
2.2, AI	0.435	2.06	-1.63	-78.9%	-0.98	59.9%
2.2, AII	0.435	2.20	-1.76	-80.2%	-0.97	54.8%
2.2, BI	0.566	2.05	-1.49	-72.4%	-0.97	65.0%
2.2, BII	0.566	2.20	-1.63	-74.2%	-0.97	59.3%
2.2, CI	0.566	2.05	-1.49	-72.4%	-0.97	65.0%
2.2, CII	0.566	2.20	-1.63	-74.2%	-0.97	59.3%
2.3, AI	0.502	2.11	-1.61	-76.3%	-1.03	63.7%
2.3, AII	0.502	2.26	-1.76	-77.8%	-1.03	58.5%
2.3, BI	0.612	2.11	-1.50	-71.1%	-1.03	68.4%
2.3, BII	0.612	2.26	-1.65	-72.9%	-1.03	62.4%
2.3, CI	0.356	2.11	-1.76	-83.2%	-1.03	58.4%
2.3, CII	0.356	2.26	-1.90	-84.3%	-1.03	54.0%

You may be aware of these studies, but I thought I would pass them along just in case.

And thank you for the V2 presentation today!

-Amit

From: Missimer, Katie [mailto:Katie_Missimer@afandpa.org] **On Behalf Of** Noe, Paul
Sent: Thursday, December 05, 2013 10:37 AM
To: Srivastava, Amit; Dunkins, Robin; Spence, Kelley
Cc: Noe, Paul
Subject: NCASI Manufacturing Residuals Study

Amit, Robin and Kelley:

Attached is the NCASI Manufacturing Residuals Study that we mentioned during our meetings with you. Also attached is AF&PA and AWC's summary of the study.

If you have any questions please feel free to contact me.

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Vice President for Public Policy
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**Study Shows Carbon Neutrality of Biomass Manufacturing Residuals
Used for Energy in Forest Products Industry**

A recent study by the National Council for Air and Stream Improvement (NCASI)[1] has found substantial greenhouse gas reduction benefits from using manufacturing residuals for biomass energy in the forest products industry. The study, "Greenhouse Gas and Fossil Fuel Reduction Benefits of Using Biomass Manufacturing Residuals for Energy Production in Forest Products Facilities," examined the life cycle greenhouse gas and fossil fuel reduction benefits of using biomass residuals for energy production in the U.S. forest products industry. Wood processing activities at pulp, paper and wood products mills produce a significant volume of biomass residuals, and they are the primary source of energy to run the mills. On average, about two-thirds of the energy powering forest products mills is derived from biomass. The study shows:

- There are substantial greenhouse gas reduction benefits in using biomass manufacturing residuals for energy in the forest products industry. Each year, the use of such biomass avoids the emission of approximately 218 million metric tons of CO2e. (This is equivalent to removing over 40 million cars from the road.)
- The benefits of using biomass residuals for energy, rather than disposing of them, have been rapidly realized:
    - Considering a weighted average of all residuals reflecting the volumes of their use, their greenhouse gas reduction benefits are superior to fossil fuels within much less than a year.
    - Even if the benefits of displacing fossil fuels with biomass residuals are ignored, on average using biomass residuals for energy produces within 2.4 years lower cumulative greenhouse gases emissions than disposal.
    - When considering its ongoing production and use of biomass energy over many years, the U.S. forest products industry is producing net greenhouse gas benefits by using biomass energy as its major energy source.
- If the U.S. forest products industry did not use biomass residuals and relied solely on fossil fuels for energy, the ultimate releases of greenhouse gases would more than quadruple.

This underscores the importance of policymakers continuing to recognize the forest products industry's use of biomass energy as carbon neutral.

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[1] The National Council for Air and Stream Improvement (NCASI) is an independent, non-profit research institute that focuses on environmental and sustainability topics relevant to forest management and the manufacture of forest products.

ncasi

NATIONAL COUNCIL FOR AIR AND STREAM IMPROVEMENT

GREENHOUSE GAS AND FOSSIL FUEL

REDUCTION BENEFITS OF USING

BIOMASS MANUFACTURING RESIDUALS

FOR ENERGY PRODUCTION IN

FOREST PRODUCTS FACILITIES

TECHNICAL BULLETIN NO. 1016

OCTOBER 2013

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PRESIDENT'S NOTE

NCASI continues its work to address the United States Environmental Protection Agency's expressed interest in the life cycle greenhouse gas benefits associated with using biomass. The regulatory decisions EPA makes on this topic have the potential to greatly affect the costs of doing business and the perception of the forest industry's products in the marketplace. The forest products industry, therefore, has a great deal at stake in ensuring that the agency's deliberations on this topic are well informed.

In an earlier report, NCASI examined the life cycle greenhouse gas and non-renewable energy benefits of using black liquor in the kraft recovery system. In the study described herein, NCASI extends this work to other types of biomass-based manufacturing residuals used for energy generation within the industry. While there are numerous studies examining the life cycle impacts of biomass energy, none has applied the comprehensive approach used here by NCASI to characterize the impacts of the industry's use of energy produced from biomass residuals.

In this study, NCASI has compared systems involving the use of biomass-based manufacturing residuals for energy to comparable systems relying on fossil fuels. The results indicate that the industry's use of these manufacturing residuals for energy avoids the release of approximately 110 million metric tons of CO_2E per year.

Combining the results of this study with the results of the previous NCASI study on black liquor reveals that each year's use of biomass-based manufacturing residuals (including black liquor) in the US forest products industry avoids the emission of approximately 218 million metric tons of CO_2E, an amount more than three times the annual direct emissions of CO_2 from fossil fuel combustion in the industry.

This study is one of a series of ongoing NCASI projects having the objective of helping the forest products industry and its stakeholders better understand the greenhouse gas and energy impacts of using forest biomass as a raw material and fuel.

Ronald A. Yeske

October 2013

GREENHOUSE GAS AND FOSSIL FUEL REDUCTION BENEFITS OF USING BIOMASS MANUFACTURING RESIDUALS FOR ENERGY PRODUCTION IN FOREST PRODUCTS FACILITIES

TECHNICAL BULLETIN NO. 1016
OCTOBER 2013

ABSTRACT

This study examined the life cycle greenhouse gas (GHG) and fossil fuel-related benefits of using various biomass residuals for energy production within the forest products industry, including pulp and paper mills and wood products manufacturing facilities. More specifically, woody mill residuals (e.g., bark, sawdust, etc.), wastewater treatment plant residuals, and paper recycling residuals (i.e., materials removed during processing of recovered fiber to eliminate contaminants and yield reusable fiber) were studied. Two product systems were compared: a product system in which the biomass residuals are burned for energy in a forest products industry facility (biomass energy system), and a product system in which the biomass residuals are disposed of and fossil fuels are used instead to generate an identical amount and form of energy (non-use system). For each residual type, various scenarios were evaluated, including one (the typical scenario) that best represents the industry average. Moreover, a variety of residual characteristics were subjected to sensitivity analyses.

For all residuals studied, except paper recycling residuals, the system using residuals for energy produced GHG emissions, not including biogenic CO_2, that were generally 98% lower than those from the system disposing of the residuals instead of using them for energy. Paper recycling residuals resulted in significant but lower benefits because they are comprised of a portion of plastic. Even when biogenic CO_2 was included in the analysis, the GHG emissions for typical scenarios regarding a) woody mill residuals, b) wastewater treatment plant residuals, and c) paper recycling residuals were lower in the biomass energy systems by 261 kg CO_2E/GJ, 295 kg CO_2E/GJ and 112 kg CO_2E/GJ, respectively when compared to the non-use systems. Compared to the analogous fossil fuel-based systems, fossil fuel consumption was found to be lower by more than 99% for all residuals examined in this study. The benefits of using biomass residuals for energy production start to be seen in less than one year under typical scenarios. An analysis that addressed the fate of the biogenic carbon, not considering fossil fuels substitution benefits, was also performed which showed that benefits from using residuals for energy, including black liquor, start to be achieved in 0 to 7.7 years, with a weighted average of 2.4 years.

The current annual use of the manufacturing residuals examined in this report avoids the release, over time, of approximately 110 million tonnes of CO_2E. Combining the results of this study with the results of the previous NCASI study on black liquor reveals that each year's use of biomass-based manufacturing residuals (including black liquor) in the US forest products industry avoids the emission of approximately 218 million tonnes of CO_2E, which is more than three times the annual direct emissions of CO_2 from fossil fuel combustion in the industry.

KEYWORDS

biomass residuals, energy, greenhouse gases, life cycle assessment

RELATED NCASI PUBLICATIONS

Technical Bulletin No. 984 (April 2011). *Greenhouse gas and non-renewable energy benefits of black liquor recovery*.

GREENHOUSE GAS AND FOSSIL FUEL REDUCTION BENEFITS OF USING BIOMASS MANUFACTURING RESIDUALS FOR ENERGY PRODUCTION IN FOREST PRODUCTS FACILITIES

TECHNICAL BULLETIN NO. 1016
OCTOBER 2013

EXECUTIVE SUMMARY

Wood handling and processing activities in log yards, sawmills, pulp and paper mills, and other forest products activities produce a significant amount of residuals, most of which consist of black liquor, bark, sawdust, shavings, and other woody debris. These currently available residuals are increasingly being used as a source of renewable energy.

There have been a rapidly increasing number of life cycle assessment (LCA) studies of energy produced from woody biomass. Studies have mainly focused on electricity generation and district heating. In those instances where studies have addressed the use of woody biomass residuals by forest products facilities (e.g., sawmills), they typically have not considered alternative fates for the residuals. In addition, while not traditionally considered in typical LCA studies, the timing of emissions may be an important consideration in some contexts.

ES.1   Objective

The overall objective of this study was to evaluate the life cycle (cradle-to-final energy analysis) greenhouse gas (GHG) and fossil fuel reduction benefits of using various forms of forest biomass residuals (manufacturing-related) for energy production in forest products manufacturing facilities in contrast to no beneficial use of these residuals coupled with production of the same quantity and form of energy using fossil fuels. This study supplements a previous NCASI study that analyzed the greenhouse gas reduction benefits of using spent pulping liquor, known as black liquor, for energy in the forest products industry, for which the results are also summarized in this study to present a comprehensive picture of the benefits of the industry's use of forest biomass residuals for energy production.

This study also included two secondary objectives: 1) to analyze the emissions of biogenic greenhouse gases (GHGs) directly released from the units in which the residuals are managed (i.e., combustion units or landfills, also called a gate-to-gate analysis) and 2) to analyze the annual/cumulative emissions attributable to the use of the residuals for energy as an ongoing, long-standing practice (both in terms of cradle-to-final energy and gate-to-gate boundaries).

The biomass residuals specifically studied in this project were

- woody mill residuals (e.g., bark, sawdust and other similar manufacturing residuals from sawmills, panel plants, and pulp and paper mills);
- wastewater treatment plant (WWTP) residuals; and
- paper recycling residuals (e.g., old corrugated container (OCC) rejects)[1].

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[1] Paper recycling residuals are materials removed during processing to eliminate contaminants and yield reusable fiber. They generally consist of a fiber and plastic fraction.

ES.2   Methods

ES.2.1 Methods for the Cradle-to-Final Energy Analysis

For each type of residual, the study compared two different product systems:

1) one in which the biomass residuals are burned for energy (**biomass energy system**); and
2) one in which the biomass residuals are disposed of and fossil fuels are used instead to generate an identical amount and form of energy (**non-use system**).

More specifically, the methodology used in this study followed life cycle principles by calculating emissions from "cradle to final energy," including fuel conversion efficiency. The primary functional unit employed in this study was ***the production of 1 GJ of energy***. It is important to note that whether manufacturing residuals are used for energy or disposed of, the same number of trees would be harvested and the same quantity of resources would be required to produce the related forest products.

The overall analysis approach employed in this study is as follows. First, for each system component of the study (size reduction, biomass energy production, alternative fate of the residuals and fossil fuel displaced), several scenarios were defined. These scenarios were intended to represent a broad range of conditions in the US forest products industry. Then, a typical scenario was defined for each residual type representing the best estimate of average conditions in the US in terms of the system components mentioned above. The typical scenario was analyzed to determine 1) typical benefits obtained by using a given residual type, 2) the contribution of each different system component to the overall results, 3) the sensitivity of various parameters (i.e., biomass properties such as higher heating value, water content, etc.) to the results, and 4) the timing of emissions. Where possible, each parameter was analyzed using a base case, low, and high value. Finally, a number of system configuration scenarios were also analyzed.

The difference in greenhouse gas impact (GHGI) between product systems was determined by calculating the differences in annual GHG emissions from the systems and determining the cumulative radiative forcing impacts associated with these differences over time, out to 100 years. The difference in GHGI between the two systems was calculated twice, once with biogenic CO_2 included in the analysis and once with biogenic CO_2 excluded. In addition to characterizing the total difference in GHGI over 100 years, this study examined the implications of using biomass residuals for energy as a function of time. When residuals are burned for energy, the biogenic carbon is immediately released to the atmosphere. In contrast, residuals placed into landfills degrade and release the carbon over time.[2] In such cases, the emissions from the biomass energy system could sometimes be higher in the short term than those from the non-use system, but the emissions from the non-use system overtake those from the biomass energy system relatively quickly. For each residual, this study computed the number of years required for the cumulative radiative forcing associated with the emissions from the non-use system to equal the cumulative radiative forcing associated with the emissions from the biomass energy system (referred to as the "break-even time" in this report). After

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[2] The results of an earlier study of the benefits of using black liquor are also included in this report. For black liquor, it is difficult to construct an alternative fate scenario because the material is integral to pulp production. Nonetheless, in the earlier study it was assumed that, if not used in the kraft recovery cycle, black liquor would be incinerated or treated in aerobic wastewater treatment plants. In both cases, the carbon returns to the atmosphere far too rapidly for carbon storage to be important in the calculations. It was assumed that all carbon is emitted as biogenic CO_2. If, however, some of the carbon was emitted as methane, the benefits of using the liquor in the kraft recovery cycle would be greater than estimated in the previous study.

this point, the cumulative radiative forcing associated with the non-use system remains higher than that associated with the biomass energy system for the remainder of the 100-year period. Dynamic calculations of cumulative radiative forcing were used in the analysis rather than conventional global warming potentials because the intent was to capture the time-dependent impacts of each system, which is not possible using global warming potentials which assess cumulative radiative forcing over a single period (e.g., 100 years).

The difference in fossil fuel consumption between the two systems use was also calculated.

ES.2.2 Methods for Additional Analyses

In addition to the life cycle analyses described above, two secondary analyses were undertaken.

The first involved limiting the analysis to the fate of the biomass carbon, without regard to fossil fuel substitution benefits. In this analysis, the two compared systems (i.e., the biomass energy system and the non-use system) have been compared in terms of the emissions coming directly out of the units receiving the residuals (i.e., combustion units or landfills). In the case of paper recycling residuals, only the fiber fraction was considered as the focus here was on the fate of the biomass carbon. The results were computed for two indicators: difference in GHGI over 100 years and break-even time.

The second analysis consisted of changing the frame of analysis to evaluate the annual/cumulative emissions attributable to the ongoing use of the residuals. For this analysis, a different functional unit was used, defined as *the yearly production of 1 GJ of energy as an ongoing practice*. The differential GHGI indicator was computed on a yearly basis so as to estimate when in the past the practice would have had to begin in order for the difference in GHGI to become zero in 2014. These results were computed both for the full life cycle (i.e., including fossil fuel substitution) and for the more constrained analysis looking only at the biogenic GHG emissions from the units receiving the residuals.

ES.3   Results from the Cradle-to-Final Energy Analysis, Including the Benefits of Displacing Fossil Fuels

ES.3.1 Difference in GHGI, Including Biogenic CO_2

Table ES.1 summarizes the differences in life cycle GHG impact, over 100 years, between the systems using residuals for energy and the systems using fossil fuels when biogenic CO_2 is included in the emissions. The negative values in this table indicate that the biomass energy system produced less impact than the non-use system. When considering a weighted average of all residuals used by the industry, including black liquor, the biomass energy systems produced an emissions impact that was lower by 208 kg CO_2E/GJ when compared to the non-use systems. Given current practice, this means that the use of manufacturing residuals (including black liquor) in the industry for one year avoids approximately 218 million tonnes CO_2E, which is more than three times the annual direct emissions (Scope 1) associated with the combustion of fossil fuels in the forest products industry.

The reduction occurs across a range of system configuration scenarios (boiler type, assumptions about the displaced fossil fuel, the GHG intensity of the electricity grid, and the level of cogeneration at forest products facilities) and without affecting the amount of wood harvested or the amount of forest products produced.

Table ES.1 Difference in Total Life Cycle GHG Emissions (including Biogenic CO$_2$):
Biomass Energy System Compared to Comparable Fossil Fuel-Based System
Where the Residuals are Disposed

Residual Type	Differential GHGI: Difference in Emissions Impact for Typical Scenario (kg CO$_2$E/GJ)
Woody mill residuals	-261
WWTP residuals	-295
Paper recycling residuals	-112
Black liquor	-182
Weighted average of biomass manufacturing residuals	-208

ES.3.2 Relative Difference in GHGI, Excluding Biogenic CO$_2$

Table ES.2 summarizes the differences in life cycle GHG emissions impacts, over 100 years, between the systems using residuals for energy and the systems using fossil fuels when biogenic CO$_2$ is excluded from the life cycle emissions. The negative results in this table indicate that the biomass energy system produces a smaller greenhouse gas impact than the non-use system. Using woody mill residuals and WWTP residuals for energy produces a reduction in impact from non-biogenic CO$_2$ GHGs of at least 98% compared to the non-use systems, across all system configuration scenarios and sensitivity analyses. Paper recycling residuals also result in significant, but lower, benefits (86.4% reduction in the typical scenario) mainly because these residuals are comprised of a portion of plastic. The previous study of black liquor by NCASI showed emissions of non-biogenic CO$_2$ GHGs that were lower by 90.5% for a system using black liquor in the kraft recovery system compared to a comparable system based on fossil fuels. When considering a weighted average of all manufacturing residuals used by the industry under their typical scenarios, including black liquor, the biomass energy system produced an emissions impact attributable to non-biogenic CO$_2$ GHGs that was 93.3% lower than those from the defined non-use system.

Table ES.2 Life Cycle GHG Emissions, Not Including Biogenic CO$_2$: Percent Difference
in GHG Impact between the Biomass-Based System and the Comparable Fossil Fuel-Based System
Where the Residuals are Disposed

Residual Type	Relative GHGI: Difference in Typical Scenarios (%)
Woody mill residuals	-99.1
WWTP residuals	-98.7
Paper recycling residuals	-86.4
Black liquor	-90.5
Weighted average of biomass manufacturing residuals	-93.3

ES.3.3 Emissions Timing

While not traditionally considered in LCA studies, the timing of emissions can be an important consideration for certain policy discussion/design contexts. When residuals are burned for energy, the biogenic carbon is immediately released to the atmosphere. In contrast, residuals placed into landfills release carbon over time. This delay is one of the reasons why forest biomass energy systems can

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initially emit more GHGs than the corresponding fossil fuel systems which dispose of the residuals. In a relatively short period, however, the cumulative radiative forcing associated with emissions from the fossil fuel systems becomes greater than that from the corresponding biomass systems due to the GHGs (including methane) produced by the decaying residuals and the GHG emissions from fossil fuel combustion. An assessment performed to address the timing of benefits produced the results summarized in Table ES.3. The results indicate that, when fossil fuel substitution is considered, it takes less than one year for the cumulative radiative forcing associated with the biomass energy system to be less than that associated with the non-use system.

Table ES.3   Time for Biomass Energy Systems to Have Lower Cumulative Radiative Forcing from GHG Emissions (Including Biogenic CO_2) Than the Corresponding Non-Use Systems

Residual Type	Break-Even Time: Typical Scenarios (years)
Woody mill residuals	0.6
WWTP residuals	0
Paper recycling residuals	0
Black liquor	0
Weighted average of biomass manufacturing residuals	0.2

ES.3.4 Fossil Fuel Consumption

Table ES.4 summarizes the results obtained for the Fossil Fuel Consumption indicator. The negative values in this table indicate that the biomass energy systems use less fossil fuel than the corresponding non-use systems. For all residual types analyzed in this report, considering all system configuration scenarios and sensitivity analyses performed, it was shown that fossil fuel consumption was lower by more than 98% in the biomass energy systems compared to the non-use systems. Note that a previous study by NCASI showed 89.8% lower fossil fuel consumption for a system using black liquor when compared to a scenario based on fossil fuel. When considering a weighted average of all residuals used by the industry, including black liquor, the biomass energy systems used 93% less fossil fuel when compared to the defined non-use system.

Table ES.4   Fossil Fuel Consumption: Percent Difference between the Biomass-Based Systems and the Comparable Fossil Fuel-Based Systems Where the Residuals are Disposed

Residual type	Relative Fossil Fuel Consumption: Difference in Typical Scenarios (%)
Woody mill residuals	-100
WWTP residuals	-99.3
Paper recycling residuals*	-99.9
Black liquor	-89.8
Weighted average of biomass manufacturing residuals	-93.1

*Considering that the plastic fraction of paper recycling residuals is not a new input of fossil fuel.

ES.4   Results from Additional Analyses

ES.4.1 Analysis of Biogenic GHGs, Ignoring Fossil Fuel Displacement (Gate-to-Gate Analysis)

All the results presented above were computed using a life cycle approach that considered the fossil fuels being displaced by biomass residuals. The typical scenarios for the two product systems (i.e., one system using residuals for energy and the other system managing the residuals by some other means) have also been compared in terms of the emissions coming directly out of the units receiving the residuals (i.e., combustion units or landfills). In this analysis, the benefits of fossil fuel substitution were ignored.

As shown in Table ES.5, even in this highly constrained analysis, using the biomass residuals for energy generation resulted in significantly lower GHG impact. A significant fraction of the emissions benefits were attributable to avoidance of landfill methane. A previous, similarly constrained analysis on black liquor assumed that the alternative management scenario would almost certainly involve returning the biogenic carbon in the liquor to the atmosphere. To be conservative, it was assumed in that study that the carbon would return to the atmosphere as CO_2 via incineration or treatment in aerobic wastewater treatment plants. This resulted in net zero biogenic GHG releases for energy production compared to an alternative fate. The reduction in biogenic GHG emissions impact over 100 years associated with the use of all manufacturing residuals (weighted according to usage), including black liquor, was shown to be 51 kg CO_2E/GJ.

When the benefits of fossil fuel displacement are ignored, it takes longer for the biomass energy systems to arrive at the point where cumulative radiative forcing is lower than for the corresponding non-use systems. Considering only biogenic emissions, the biomass energy systems required from 0 to 7.7 years, with a weighted average of 2.4 years for typical scenarios (including black liquor), to produce lower cumulative radiative forcing.

Table ES.5 Results of Analysis of Biogenic GHGs, Ignoring Fossil Fuel Displacement

Residual Type	Difference in Biogenic GHGI (kg CO₂E/GJ)	Break-Even Time (years)
Woody mill residuals	-154	7.4
WWTP residuals	-190	5.9
Fiber fraction of paper recycling residuals*	-132	7.7
Black liquor	0	0
Weighted average of manufacturing residuals	-51.1	2.4

* In addition to biomass, paper recycling residuals contain plastics which are produced from fossil fuels. For the purpose of the biomass carbon fate analysis, only the biomass fraction was considered.

ES.4.2 GHG Emissions from Ongoing Use of Residuals for Energy Production

The analysis above examined the impact over time associated with producing 1 GJ of energy on a one-time basis. The practice of burning residuals for energy, however, is long-standing in the forest products industry. It is also of interest, therefore, to examine the net impact from using residuals for energy on an ongoing basis. To do this, one can compare two facilities that are identical, except that one burns residuals for energy year after year while the other facility disposes of the residuals and uses fossil fuels for energy instead. Table ES.6 below, based on the typical scenarios used elsewhere in this study, shows the year when ongoing practices would have to have been initiated in order for the facilities using the residuals for energy production to show net benefits, in terms of cumulative

radiative forcing, in 2014. The table also contains information on the industry's past use of these materials for energy. For the weighted average mix of biomass manufacturing residuals used by the industry, even limiting the analysis to biogenic emissions (ignoring the benefits of fossil fuel displacement), the facility using residuals for energy would be showing net benefits as long as it had started this practice by 2008.

Table ES.6 Ongoing Use of Residuals for Energy Production: Comparing Facilities Using Biomass Residuals for Energy with Similar Facilities Using Fossil Fuels for Energy and Disposing of the Residuals

Residual		Year in the Past When Ongoing Practice Would Have Had To Be Initiated for Cumulative Radiative Forcing from the Two Facilities To Be Equal in 2014 (under typical scenario)	Past Industry Practice in Using the Residuals for Energy
Woody mill residuals	With benefits of the displaced fossil fuels	2012	Based on AF&PA statistics, in 1971, woody mill residual represented 7% of the fuel (16% of the biomass) burned at pulp and paper mills. Wood residuals have been used in saw mills going back to the mid-1800s.
	Without benefits of the displaced fossil fuels	1998	
WWTP residuals	With benefits of the displaced fossil fuels	2014	NCASI statistics on WWTP residuals management go back to 1979, at which point 11% of these residuals was being burned for energy.
	Without benefits of the displaced fossil fuels	2001	
Paper recycling residuals	With benefits of the displaced fossil fuels	2014	NCASI has published information showing the use of recycling residuals for energy in 1975.
	Without benefits of the displaced fossil fuels	1997	
Black liquor	With benefits of the displaced fossil fuels	2014	Based on AF&PA statistics, in 1971, 35% of the fuel (84% of the biomass) burned at pulp and paper mills was black liquor. By 1980, this had increased to 40% of the fuel (79% of the biomass).
	Without benefits of the displaced fossil fuels	2014	
Weighted average of biomass manufacturing residuals	**With the benefits of the displaced fossil fuels**	**2013**	**N/A**
	Without the benefits of the displaced fossil fuels	**2008**	

†Fiber fraction only.

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ES.5   Conclusions

In this study, the GHG and fossil fuel-related benefits of using woody manufacturing residuals, recycling residuals, and wastewater treatment plant residuals for energy production within the forest products industry were analyzed using life cycle principles and other methods. It was shown that using all types of residuals for energy production produces significant benefits both in terms of reduced fossil fuel consumption and reduced greenhouse gas emissions impacts. This result is valid across a range of system configuration scenarios (boiler type, assumptions about the displaced fossil fuel, the GHG intensity of the electricity grid, and the level of cogeneration at forest products facilities), residual characteristics (e.g., heating value, moisture content), and whether or not the benefits from fossil fuel substitution are considered. These findings hold true whether biogenic CO_2 is included in the analysis or excluded by giving it an emission factor of zero (equivalent to what is sometimes called "carbon neutrality").

The specific GHG results, including biogenic CO_2, for the individual residuals and for the weighted average industry residuals are summarized in Tables ES.2 and ES.3. The benefits occur without affecting the amount of wood harvested or the amount of wood products produced. It typically takes less than 0.6 years for the cumulative radiative forcing associated with emissions from the biomass energy system to be lower than that of the corresponding non-use system, with a weighted average (reflecting industry's typical use of residuals) of less than 0.2 years. Even ignoring the benefits of displacing fossil fuel and limiting the analysis to biogenic emissions, the cumulative radiative forcing impacts associated with emissions from the biomass energy systems are lower than those from the non-use systems in 0 to 7.7 years, depending on the residual, with a weighted average of 2.4 years.

When considered as an ongoing practice (e.g., ongoing production of 1 GJ energy per year), and when displaced fossil fuels are considered, net benefits from using residuals for energy are observed in two years or less. In the case where the benefits of displacing fossil fuels are ignored, the break-even times are longer, but even in this case, considering the weighted average mix of residuals used in the industry, it takes 6 years to realize net benefits from using manufacturing residuals for energy. This means that a facility that began using the average mix of residuals for energy in 2008 would be showing net benefits on an ongoing basis in 2014, even ignoring the benefits of displacing fossil fuels. Black liquor and woody mill residuals comprise 95% of the biomass residuals used in the industry for energy. Kraft black liquor has been commonly burned for energy and chemical recovery since at least the 1950s when the kraft pulping process became widespread. Woody mill residuals have been used for energy at forest products manufacturing facilities since the 1800s.

The GHG emissions reduction benefits of using manufacturing residuals for energy in the forest products industry are large. Given current practice, the use of manufacturing residuals (including black liquor) in the industry for one year avoids an emissions impact of approximately 218 million tonnes CO_2E, equal to more than three times the annual direct emissions associated with the combustion of fossil fuels in the forest products industry.

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GREENHOUSE GAS AND FOSSIL FUEL REDUCTION BENEFITS OF USING BIOMASS MANUFACTURING RESIDUALS FOR ENERGY PRODUCTION IN FOREST PRODUCTS FACILITIES

1.0 INTRODUCTION AND BACKGROUND

1.1 Background

The use of wood for energy has attracted considerable attention as a greenhouse gas mitigation option (FAO 2008). The United States (US) and Canada are among the largest OECD[3] users of wood for industrial bioenergy, primarily from indirect sources including black liquor and other manufacturing residuals (FAO 2008; Steierer et al. 2007). Wood harvesting and handling, as well as processing activities in log yards, pulp and paper mills, sawmills, and other forest products activities produce a significant amount of residuals, most of which consist of bark, sawdust, shavings, and harvest residuals and other woody debris. These residuals are increasingly being used as a source of renewable energy. Often, however, the residuals that are not beneficially used are either incinerated or placed in a municipal or on-site industrial landfill.

Recent years have seen both a rise in the interest in substituting biomass for fossil fuels and in the skepticism about the greenhouse gas (GHG) benefits of this substitution. While programs that promote the use of biomass as a substitute for fossil fuel have important connections to the issues of energy security and economic sustainability, it is the questions about greenhouse gas mitigation benefits that have been at the center of the debate on whether and how to increase the reliance on the use of biomass for energy.

An important distinction between biomass carbon (also known as biogenic carbon) and the carbon in fossil fuels is that biogenic carbon was only recently removed from the atmosphere. When biomass is burned, decays, or is otherwise oxidized, the resulting CO_2 is returned to the atmosphere. The net transfers of biogenic carbon to the atmosphere can be zero if the uptake of carbon (in CO_2) by growing trees is equivalent to the biogenic carbon released in the combustion and decay of biomass (sometimes referred to as representing "carbon neutrality"). Where the amounts of biogenic CO_2 that return to the atmosphere are less than the amounts removed, the difference represents increases in stocks of stored carbon (net removals from the atmosphere). Where net returns are greater than the amounts removed, the difference represents depleted stocks of stored carbon.

The net transfers of biogenic CO_2 to the atmosphere associated with the production and use of biomass can be used to characterize the GHG emissions associated with a biomass energy system, often called the "carbon footprint" of the system. Understanding the impacts of using biomass for energy, however, requires a different analytical framework than used for a carbon footprint. In studying the impacts of using biomass for energy, one must consider how that energy might be produced if biomass was not used and the fate of the biomass if not used for energy. In this study, the objective was to understand the impacts of using biomass for energy so the life cycle emissions from a system using biomass for energy are compared to the life cycle emissions from alternative systems where the biomass undergoes an alternative fate and fossil fuels are used to produce an equivalent amount of energy.

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[3] Organisation for Economic Co-operation and Development.

1.2   Review of LCA Studies

In recent years, there has been a rapidly increasing number of life cycle assessment (LCA) studies of woody biomass residual energy systems. Table 1.1 provides an overview of the main studies recently published that compared woody biomass residual energy systems with fossil fuel-based energy systems and focused on direct energy production from the residuals, not including studies looking at liquid biofuels. Only studies published in the peer-reviewed literature are presented in this table. The overview does not purport to be exhaustive.

It can be seen from Table 1.1 that these studies have mainly focused on electricity generation and direct heating and that, in cases where the authors looked at the use of woody biomass residuals by forest products facilities (e.g., sawmills), they typically did not consider alternative fates for the residuals. It is also interesting to note that there are very few studies covering other manufacturing residuals from the forest products industry, such as wastewater treatment residuals and paper recycling residuals, and their use for energy production.

In addition, while not traditionally considered in typical LCA studies, the timing of emissions may be an important consideration for certain policy discussion/design contexts. When residuals are burned for energy, the biogenic carbon is immediately released to the atmosphere. In contrast, residuals placed into landfills or left on forest sites degrade slowly, releasing carbon over time. In these cases, the emissions from burning biomass for energy could be higher in the short term than those associated with disposing of the biomass, but this is generally compensated for relatively quickly by the benefits from fossil fuel substitution or benefits from avoiding the disposal emissions of the biomass residuals.

Table 1.1 Published Studies Regarding Life Cycle GHG Mitigation Benefits
for Biomass Residuals Energy Systems

Study	Biomass Type	Fossil Fuel Offset	Type of Facility in Which the Biofuel Is Used	Alternative Fate Considered	GHG Mitigation[*]	Break-Even Time
Boman and Turnbull (1997)	Agricultural residuals, energy crops, forest harvest residuals and sawmill residuals	Coal (power)	US power plants/pulp mill	Not considered	> 90%	Not applicable
Mann and Spath (2001)	Various woody residuals	Coal (power, cofiring)	US power plants	46% landfilling, 54% mulch or conversion to short-lived products	123%[†]	Not available
Robinson et al. (2003)	Forest harvest and agriculture residuals	Coal (power, cofiring)	US power plants	Not considered	≈ 95%	Not applicable
Wihersaari (2005)	Forest harvest residuals	Coal, peat	Finnish power plant	Decomposition in forest	> 75%	Not available
Pehnt (2006)	Forest harvest residuals, woody biomass energy crops, waste wood	German energy mix (power, home heating)	German power plants and homes	Not considered	85-95%	Not applicable
Petersen Raymer (2006)	Fuel wood, sawdust, wood pellets, demolition wood, briquettes, bark	Coal (power, cofiring) and oil (home heating)	Power plants (imports to Norway), Norwegian homes, sawmills, large combustion facilities	Not considered	81-98%	Not applicable
Kirkinen et al. (2008)	Forest harvest residuals (other biomasses not considered here)	Coal, natural gas	Finnish energy sector	Decomposition in forest	Not available	< 20 years‡
Cherubini et al. (2009)	Forest harvest residuals	Various fossil fuels used for heat, power and CHP	Various	Unknown	70-98%	Not applicable

(Continued on next page. See notes at end of table.)

Table 1.1 (Cont'd)

Study	Biomass Type	Fossil Fuel Offset	Type of Facility in Which the Biofuel Is Used	Alternative Fate Considered	GHG Mitigation[*]	Break-Even Time
Froese et al. (2010)	Forest harvest residuals	Coal (power, cofiring)	US Great Lakes region power plants	Not considered	100%	Not applicable
Jones et al. (2010)	Forest harvest residuals	Natural gas, distillate oil (heat)	Unspecified	Burn at landing	≈ 40-50%‡	Not applicable
Puettmann and Lippke (2012)	Sawmill biomass residuals, pellets, forest harvest residuals	Natural gas (heat, power)	US sawmills	Not considered	57-66%§	Not applicable
Repo et al. (2012)	Forest harvest residuals	Coal, heavy oil, natural gas	Unspecified Finnish facility	Decomposition in forest	29-81%**	< 100 years
Ruhul Kabir and Kumar (2012)	Agricultural residuals, forest harvest residuals	Coal (power, cofiring)	Canadian power plants	Not considered	74-88%*	Not applicable
Zanchi et al. (2012)	Forest harvest residuals	Coal, oil, natural gas	Austrian power plants	Decomposition in forest	76-85%**	0 - 16 years
Gaudreault et al. (2012)	Black liquor	Coal, natural gas (heat and power); US electricity grid	US pulp and paper mills	Biogenic carbon released into CO_2	69-92%	Not applicable

[*]Percent for full substitution; for cofiring situations the mitigation pertains to the cofire rate (e.g., if 10% fossil fuel is replaced by biomass and emissions decrease by 9%, mitigation of 90% is assigned); includes all GHGs excluding biogenic CO_2. † Mitigation greater than 100% due to avoided end-of-life methane emissions. ‡Estimated. §One of the reasons why Puettmann and Lippke obtained lower mitigation results than other authors for manufacturing residuals is that they allocated a fraction of the load from manufacturing to the residuals. **Values at 100 years.

2.0   STUDY OBJECTIVES

The main objective of this study was to evaluate the life cycle (cradle-to-final energy analysis) greenhouse gas impact (GHGI) and fossil fuel reduction benefits of using various forms of forest biomass residuals (manufacturing-related) for energy production in forest products manufacturing facilities in contrast to no beneficial use of these residuals coupled with production of the same quantity and form of energy using fossil fuels. The total 100-year and yearly impacts were investigated.

The study also included two secondary objectives: 1) to analyze the greenhouse gas impact from the emissions of biogenic GHGs released from the units in which the residuals are managed (i.e., combustion units or landfills, gate-to-gate analysis); and 2) to analyze the annual and cumulative greenhouse gas impact associated with the net emissions attributable to the use of the residuals for

energy as an ongoing, long-standing, practice (both in terms of cradle-to-final energy and gate-to-gate boundaries).

The biomass residuals studied in this project were

- woody mill residuals (e.g., bark, sawdust, and other similar manufacturing woody residuals from sawmills, panel plants, and pulp and paper mills);
- wastewater treatment plant (WWTP) residuals; and
- paper recycling residuals (e.g., old corrugated container (OCC) rejects)[4].

For each type of residuals, the study compared a base case of no beneficial use of residuals (including their alternative fates) with 100% use for energy generation. Note that whether or not these residuals are used for energy production, the same number of trees would be harvested and the same quantity of resources would still be required to produce the related forest products. In addition to heat production, the study also included combined heat and power (CHP) as a second option for using the residuals. Other options for processing or using the wood residuals (e.g., torrefaction, gasification, hydrolysis and fermentation, other beneficial uses) were not analyzed.

3.0   INTENDED APPLICATION AND TARGETED AUDIENCE

The intended application is to inform the discussion and development of policies that require an understanding of the impacts of using biomass-based manufacturing residuals for energy at forest products manufacturing facilities. The targeted audience of this report is individuals interested in understanding these impacts.

4.0   METHODS

4.1   Cradle-to-Final Energy Analysis

4.1.1   Overview Methodology Employed

Life Cycle Assessment (LCA) is the *"compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle,"* the life cycle being *"consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal"* (ISO 2006a, p. 2).

LCA principles and methodology are framed by a set of standards (ISO 2006a, b) and technical reports and specifications (ISO 2002, 2012a, b) from the International Organization for Standardization (ISO). ISO describes LCA methodology in four phases:

1) **Goal and scope definition,** in which the aim of the study, the product system under study, its function and functional unit, the intended audience, and the methodological details on how the study will be performed are defined;
2) **Life cycle inventory analysis (LCI),** which is the *"phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle"* (ISO 2006a, p. 2);

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[4] Paper recycling residuals are materials removed during processing to eliminate contaminants and yield reusable fiber.

3) **Life cycle impact assessment (LCIA),** which is the "phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product" (ISO 2006a, p. 2); and

4) **Life cycle interpretation,** which is the *"phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations"* (ISO 2006a, p. 2).

This study

- used widely accepted LCA concepts, such as those described in LCA ISO standards 14040 and 14044 (International Organization for Standardization (ISO) 2006a, b);
- was built on the approaches by others [e.g., US Environmental Protection Agency (EPA), Consortium for Research on Renewable Materials (CORRIM)];
- was based on known and established competitive materials and alternative fates for biomass residuals; and
- did not consider any "export" of the residuals outside the forest products industry (e.g., to utilities).

More specifically, the methodology used in this study followed life cycle principles, by calculating emissions from "cradle to final energy" including fuel conversion efficiency. However, a simplified (streamlined) LCA methodology was applied. Streamlining generally can be accomplished by limiting the scope of the study or simplifying the modeling procedures, thereby limiting the amount of data or information needed for the assessment (Todd and Curran 1999). Many different streamlining approaches can be applied. In this study, two main approaches were taken: limiting the impact assessment to two indicators (global warming, fossil fuel consumption) and for the most part using generic information. Because of this, this study does not fully comply with ISO 14044 requirements for comparative assertions disclosed publicly. However, the study aligns as much as possible with this standard.

4.1.2   Functions and Functional Units

In this study, the primary functional unit was ***the production of 1 GJ of energy***. The product systems being compared also fulfilled an additional implicit function which is the management of the quantity of residuals required to produce 1 GJ of energy. This is further discussed in Section 4.1.4.

4.1.3   Scenario and Sensitivity Analyses

The overall analysis approach employed in this study is depicted in Figure 4.1. First, for each system component of the study (size reduction, biomass energy production, alternative fates of the residuals and fossil fuel displaced), possible scenarios were defined. These scenarios were intended to represent a broad range of conditions in the US forest products industry.

Then, a typical scenario was established for each residual type as the best estimate for representing average conditions in the US in terms of the different system components mentioned above. The typical scenario was analyzed to determine typical benefits obtained by using a given residual type, the contribution of each different system component to the overall results, the sensitivity of various parameters (e.g., higher heating value, water content, etc.) to the results, and the effect of time on the results. Where possible, each parameter was analyzed using a base case, low, and high value.

Perturbation analyses were also performed. The general idea behind perturbation analyses is that perturbations of the input parameters propagate as smaller or larger deviations to the resulting output (Heijungs and Kleijn 2001). The objectives of perturbation analyses are to provide 1) a list of those input parameters for which a small imprecision already leads to important changes in the results, and 2) interesting suggestions for improving the environmental performance of the system. For each parameter tested in sensitivity analysis, a perturbation analysis was also performed and a sensitivity ratio was calculated as outlined below.

Sensitivity ratio = Percent change in output variable/Percent change in input variable

The input variable is the parameter tested in sensitivity analysis while the output variable is a given environmental indicator (see more detail in Section 4.1.6). For instance, a sensitivity ratio of +1.0 means that the score of the environmental indicator increases by 1% when the parameter value is increased by 1%. The more negative an environmental indicator score, the better the performance of the biomass energy system compared to the non-use system. The more positive or the more negative a sensitivity ratio is, the more sensitive a parameter is.

Figure 4.1 Study Overall Approach for the Life Cycle Based Analyses

4.1.4   *Product Systems Studied, System Boundaries, and Allocation*

For each type of residual, the study compared a base case of no beneficial use of residuals (while accounting for their alternative fate) with 100% use for energy generation. The different product systems studied and compared in this study are discussed next. The general approach was to include within the system boundary only the processes that were different between the biomass and non-use systems.

4.1.4.1   *Woody Mill Residuals*

Major sources of manufacturing residuals include sawmills, panel plants, and pulp and paper mills. These residuals consist primarily of bark and fine residuals (e.g., sawdust, planer shavings, sanderdust). In this study, all woody mill residuals were considered as a whole, in a single analysis. Sensitivity analyses were performed to encompass the variability in residual types (see Section 5.1).

Figure 4.2 illustrates the two product systems that were compared in the case of woody mill residuals.

1) **Biomass Energy System:** Production of 1 GJ of energy (heat or combined heat and power) using manufacturing residuals.
2) **Non-Use System:** Production of 1 GJ of energy (in the same form as in #1) using fossil fuels and alternative fate of the residuals.

Figure 4.2 also shows that the accounting started with the manufacturing-related biomass residuals and ended at the point at which the energy has been generated. All of these materials would be generated whether or not they would be used for energy generation, and thus there should be no effects on upstream processes attributable to the use of the materials for energy. Therefore, upstream emissions from the production of these materials were assumed to be the same for both systems and they were not included in the analysis.

In some cases, size reduction of manufacturing residuals is required. As depicted in Figure 4.2, three scenarios were considered regarding size reduction (SR0: no size reduction, SR1: size reduction in mobile chipper, and SR2: size reduction in stationary chipper). These processes, as well as any related upstream emissions, were included in the system boundary of the biomass energy system only as they were considered to be unnecessary in the non-use system. The system boundary of the biomass energy system also included the processes required to produce the energy at forest products facilities. Five system configuration scenarios were considered: heat production only in a stoker boiler (SB), heat production only in a fluidized bed boiler (FB), and three levels of combined heat and power (CHP1, CHP2, and CHP3) in which the heat is produced in a stoker boiler.

The non-use system included the upstream emissions for producing the fossil fuel and the energy production processes at forest products facilities or utilities. The energy produced was set to be in the same form as in the biomass energy system. Figure 4.2 shows the different system configurations that were analyzed regarding energy production in the non-use system. It was assumed that heat could be produced in forest products facilities using either coal (A) or natural gas (B). Electricity production at utilities (see Section 5.1) was assumed to be represented by the US average grid (C), coal (D), or natural gas combined cycle (E). When using woody mill residuals to produce 1 GJ of energy, an implicit secondary function is accomplished: the management of the quantity of residuals necessary to produce 1 GJ of energy (Q_R). For the two compared systems to be equivalent, it was necessary to expand the boundary of the non-use system to account for an alternative fate for these residuals. Figure 4.2 shows the two scenarios that were considered for the alternative fate of residuals in the non-use systems: 1) placed in landfills (MR1), and 2) incinerated without recovering the energy

(MR2). The typical scenario definition and rationale, and more details on the various unit processes involved in both systems, are provided in Section 5.1.

Figure 4.2 Compared Product Systems for Woody Mill Residuals

4.1.4.2   WWTP Residuals

Another manufacturing residual that was included in the study is wastewater treatment plant (WWTP) residuals. Figure 4.3 illustrates the two systems that were compared for WWTP residuals:
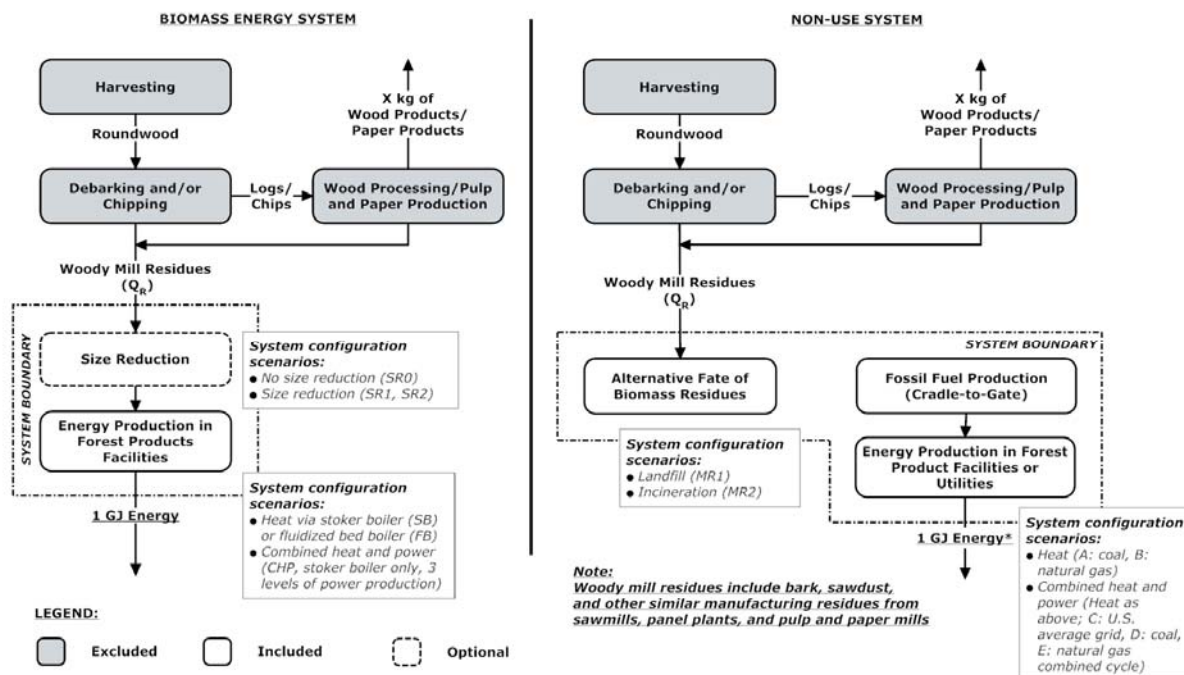
1) **Biomass Energy System:** Production of 1 GJ of energy (heat, power or combined heat and power) using the WWTP residuals; and
2) **Non-use System:** Production of 1 GJ of energy (in the same form as in #1) using fossil fuels and alternative fate of the WWTP residuals.

Figure 4.3 also shows that the accounting started with the WWTP residuals and ended at the point at which the energy has been generated. WWTP residuals would be generated whether or not they are used for energy generation, and thus there should be no effects on upstream processes attributable to the use of these materials for producing energy. Therefore, upstream emissions from the production of these materials were assumed to be the same for both systems and they were not included in the analysis. It was also assumed that mechanical dewatering would be required whether the residuals would be used for energy generation or disposed of, and hence was not included in the study.

The system boundary of the biomass energy system included the processes required to produce the energy at forest products facilities. Four system configuration scenarios were considered: heat production only in a stoker boiler (SB), and three levels of combined heat and power (CHP1, CHP2, and CHP3) in which the heat is produced in a stoker boiler.

The non-use system included the upstream emissions for producing the fossil fuel and the energy production processes at forest products facilities or utilities. Figure 4.3 shows the different system configurations that were analyzed. It was assumed that heat could be produced in forest products facilities using either coal (A) or natural gas (B). Electricity production at utilities (see Section 5.1) was assumed to be represented by the US average grid (C), coal (D), or natural gas combined cycle (E). When using WWTP residuals to produce 1 GJ of energy, an implicit secondary function is accomplished: the management of the quantity of residuals necessary to produce 1 GJ of energy (Q_R). For the two compared systems to be equivalent, it was necessary to expand the boundary of the non-use system to account for an alternative fate for these residuals. Figure 4.3 shows the two scenarios that were considered for the alternative fate of residuals in the non-use systems: 1) placed in landfills (MR1), and 2) incinerated without recovering the energy (MR2). The non-use system included the upstream emissions for producing the fossil fuel and the energy production processes at forest products facilities or utilities. The typical scenario definition and rationale, and more details on the various unit processes involved in both systems, are provided in Section 5.1.

Figure 4.3 Compared Product Systems for WWTP Residuals

4.1.4.3 *Paper Recycling Residuals*

The last manufacturing residual that was included in the study is paper recycling residuals, and more specifically old corrugated container (OCC) rejects. Figure 4.4 illustrates the two systems that were compared for paper recycling residuals.

1) **Biomass Energy System:** Production of 1 GJ of energy (heat, power or combined heat and power) using the paper recycling residuals.
2) **Non-Use System:** Production of 1 GJ of energy (in the same form as in #1) using fossil fuels and alternative fate of the paper recycling residuals.

Figure 4.4 also shows that the accounting started with the paper recycling residuals and ended at the point at which the energy has been generated. Paper recycling residuals would be generated whether or not they would be used for energy generation, and thus there should be no effects on upstream processes attributable to the use of the materials for energy. Therefore, upstream emissions from the production of these materials were assumed to be the same for both systems and they were not included in the analysis.

The system boundary of the biomass energy system included the processes required to produce the energy at forest products facilities. Four system configuration scenarios were considered: heat production only in a stoker boiler (SB), and three levels of combined heat and power (CHP1, CHP2, and CHP3) in which the heat is produced in a stoker boiler.

The non-use system included the upstream emissions for producing the fossil fuel and the energy production processes at forest products facilities or utilities. Figure 4.4 shows the different system configurations that were analyzed. It was assumed that heat could be produced in forest products facilities using either coal (A) or natural gas (B). Electricity production at utilities (see Section 5.1) was assumed to be represented by the US average grid (C), coal (D), or natural gas combined cycle (E). When using paper recycling residuals to produce 1 GJ of energy, an implicit secondary function is accomplished: the management of the quantity of residuals necessary to produce 1 GJ of energy (Q_R). For the two compared systems to be equivalent, it was necessary to expand the boundary of the non-use system to account for an alternative fate for these residuals. Figure 4.4 shows the two scenarios that were considered for the alternative fate of residuals in the non-use systems: 1) placed in landfills (MR1), and 2) incinerated without recovering the energy (MR2). The non-use system included the upstream emissions for producing the fossil fuel and the energy production processes at forest products facilities or utilities. The typical scenario definition and rationale, and more details on the various unit processes involved in both systems, are provided in Section 5.1.

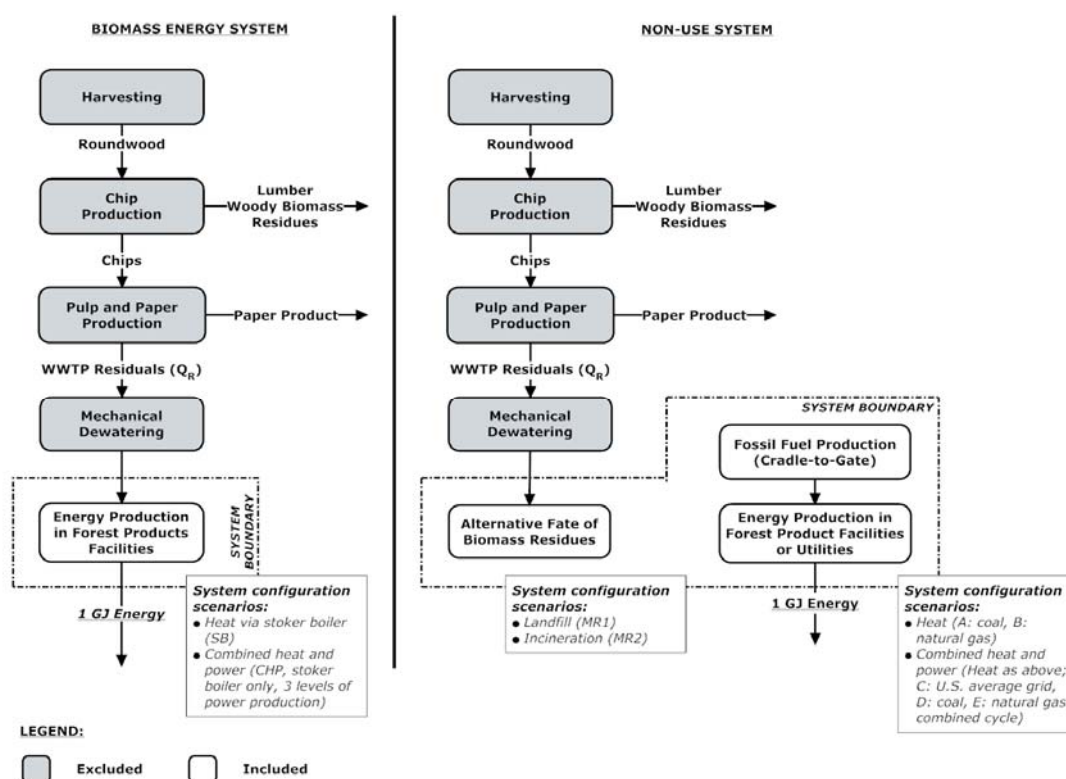**Figure 4.4** Compared Product Systems for Paper Recycling Residuals

4.1.5   Exclusions and Cut-Off Criteria
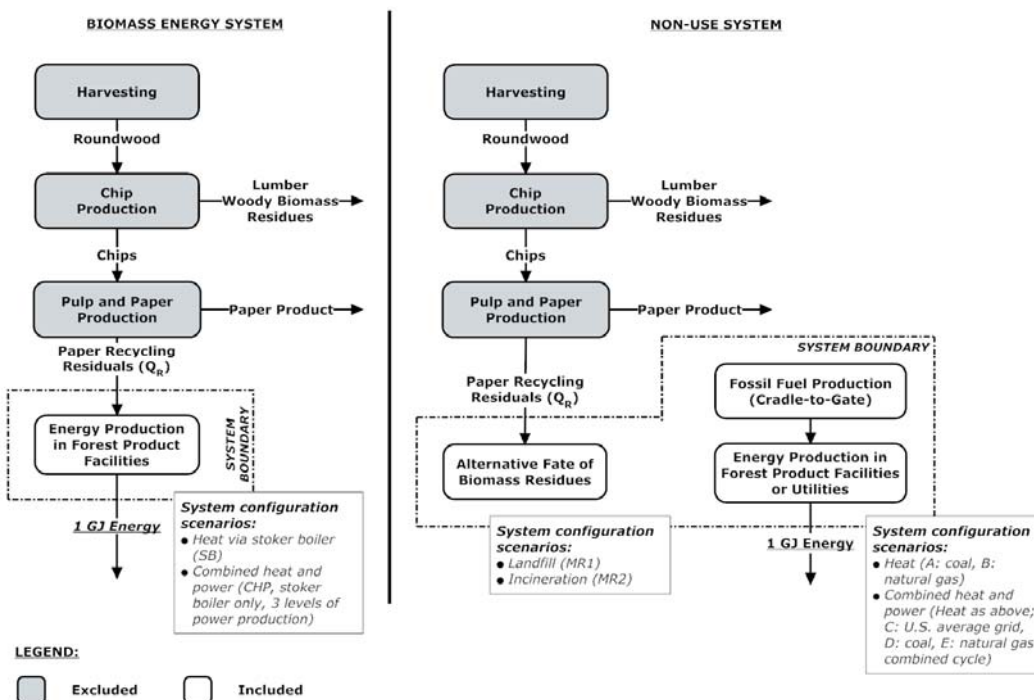
For each of the groups described above, the following components of each product system were not included in this study: manufacture of capital equipment, human activities, and unit processes common to the systems compared.

All required data were available. No cut-offs were applied.

4.1.6   Environmental Indicators Analyzed

Two main environmental aspects were studied in this study: greenhouse gases (GHGs) and fossil fuel consumption.

Note that in LCA studies, environmental indicator results are relative expressions and do not predict impacts on category endpoints, nor the exceeding of thresholds, safety margins, or risks.

4.1.6.1   Greenhouse Gas Impact (GHGI)

In this report, the term "greenhouse gas impact" is used to describe the cumulative radiative forcing over a period of time that is attributable to emissions of greenhouse gases. Various approaches can be used to calculate the greenhouse gas impact. The most common approach is to use the 100-year global warming potentials (GWPs) published by the Intergovernmental Panel on Climate Change (IPCC 2006c). The 100-year global warming potentials calculated by IPCC represent the cumulative radiative forcing over 100 years attributable to a pulse release of a GHG relative to the forcing attributable to a pulse release of the same mass of CO_2.Using this approach, the 100-year greenhouse impact is assumed to occur the same year as the pulse emission. The results are typically expressed as kilograms of CO_2 equivalents (kg CO_2E). GWPs are useful in developing GHG inventories in a way that allows the impacts associated with different types of emissions to be compared over 100 years, or some other period. IPCC has published GWPs for periods of 20, 100, and 500 years. In this study, the timing of impacts was of particular interest, which required a dynamic calculation of cumulative radiative forcing as a function of time. To accomplish this, a dynamic carbon footprinting approach developed by Levasseur (2013) and Levasseur et al. (2010) was used. This approach produces time-dependent global warming results based on the cumulative radiative forcing concept. The same scientific models are used in the dynamic carbon footprinting approach as used by IPCC to develop global warming potentials but the equations are integrated continuously over time with the exception of one element (see below). Although the results are typically expressed in units of radiative forcing (Wm^{-2}), they can also be presented in terms of kg CO_2E, especially if the objective is to compare the results to those obtained using GWPs. Approaches similar to the approach proposed by Levasseur et al. were used elsewhere (e.g., Alvarez et al. 2012).

A difference between the dynamic approach proposed by Levasseur et al. (2010) and IPCC's scientific models was mentioned above. The approach proposed by Levasseur et al. includes the radiative forcing associated with CO_2 formed when methane decomposes in the atmosphere while IPCC's GWPs for methane do not (IPCC 2007, Chapter 2, paragraph 2.10.3). Because this study is attempting to identify the difference in total impacts between systems over time, it is appropriate to include the radiative forcing associated with CO_2 produced from the decomposition of methane in the atmosphere. Simulations performed by NCASI comparing the method of Levasseur et al. to IPCC global warming potentials indicate that the effect of this difference on results is relatively small over periods of interest in this study (i.e., 100 years and less). Table 4.1 shows the results of applying the dynamic approach compared to the most recent 100-year global warming potentials from IPCC (IPCC 2006c). The results using both approaches are also shown in several places in this report.

Table 4.1 Comparison of IPCC GWPs to Results Obtained Using the Dynamic Carbon Footprint
Calculator by Levasseur et al.

GHG	20-Year		100-year		500-year	
	IPCC GWPs	Dynamic Calculator	IPCC GWPs	Dynamic Calculator	IPCC GWPs	Dynamic Calculator
Methane	72	72.9	25	27.5	7.6	10.3
Nitrous Oxide	289	289	298	298	153	153

In this study, the results for the GHGI indicator have been computed in three different ways, both for the IPCC 100-year GWPs and using the dynamic calculator.

First, the absolute difference in impact attributable to releases of GHGs over 100 years, including biogenic CO_2 emissions and removals[5] was used to calculate the results of the greenhouse gas impact indicator ("Differential GHGI") as follows:

Differential GHGI (kg CO₂E/GJ) = Total greenhouse gas impact caused by GHG releases, including biogenic CO₂ emissions and removals, for energy production using residuals – Total greenhouse gas impact of GHG releases, including biogenic CO₂ emissions and removals, for energy production using fossil fuels, including alternative fate of residuals

Or in a shorter form:

Differential GHGI (kg CO₂E/GJ) =
[Total GHGI[6]]Biomass system - [Total GHGI]Non-use system

Second, the greenhouse gases impact was computed using the percent difference in radiative forcing or GHGI impact calculated using IPCC GWPs attributable to GHGs released over 100 years, not including biogenic CO_2 ($BioCO_2$), of the biomass energy system compared to the non-use system ("Relative Non-BioCO₂ GHGI") as follows:

Relative Non-BioCO₂ GHGI (%) = (greenhouse gas impact caused by GHG releases, not including biogenic CO₂, for energy production using residuals – greenhouse gas impact caused by GHG releases, not including biogenic CO₂, for energy production using fossil fuels, including alternative fate of residuals)/(greenhouse gas impact caused by GHG releases, not including biogenic CO₂, for energy production using fossil fuels, including alternative fate of residuals)

Or in a shorter form:

Relative Non-BioCO₂ GHGI (%) =
[(GHGI, excl. BioCO₂)Biomass energy system - (GHGI, excl. BioCO₂)Non-use system]/ (GHGI, excl. BioCO₂)Non-use system

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[5] As described in Figures 4.2 to 4.4, the system boundary for the product systems did not include harvesting and forest-related activities because they are the same in the biomass and non-use systems. This means that the associated forest-related CO_2 removals, i.e., the sequestration or absorption of CO_2 from the atmosphere by the trees, were not included in this study.

[6] In this report, "Total GHG releases" is used as a short form for the sum of non-biogenic CO_2 GHGs and biogenic CO_2 GHGs.

Third, while not traditionally considered in typical LCA studies, the timing of emissions and of greenhouse gas impact may be an important consideration for certain policy discussion/design contexts. For instance, in the context of this study, timing may be important in cases where the alternative to using residuals is allowing them to decay in waste disposal sites. Therefore, this study examined the life cycle implications of using biomass residuals for energy as a function of time. For each residual, the study computed the number of years it would take for the cumulative greenhouse gas impact from the two systems to be equal (break-even time). After this time, the cumulative greenhouse gas impacts from the biomass systems remain lower than that from the non-use system for remainder of the 100-year period of study. While the Differential GHGI results are presented in terms of kg CO_2E to facilitate comparison with using the 100-year IPCC GWPs, the yearly differential impact is presented in terms of radiative forcing because the graphical results are much easier to interpret when presented in terms of radiative forcing units (Wm^{-2}).

Notes:

- The materials being examined are biomass residuals. Their use was assumed to have no effect on carbon in growing biomass or gross removals of carbon from the atmosphere by the forest.
- Carbon in products-in-use was not modeled in this study because the fate of carbon in products is not affected by the fate of the residuals.

4.1.6.2   *Fossil Fuel Consumption*

Fossil fuel used in the life cycle of each of the product systems studied was computed. The relative fossil fuel consumption ("Relative FF CON") was calculated as follows:

Relative FF CON (%) = (fossil fuel consumption score for energy production using residuals – fossil fuel consumption score for energy production using fossil fuels, including alternative fate of residuals)/(fossil fuel consumption score for energy production using fossil fuels, including alternative fate of residuals)

Fossil fuel consumption indicators are not based on an impact assessment model but rather on a quantification of the energy inputs to the studied product system. The cumulative energy demand method (Hischier and Weidema 2009) was used to quantify fossil fuel consumption because it is the most consistent with the life cycle inventory database used in this study. This method uses higher heating values in an attempt to characterize the total amount of energy consumed rather than only the energy directly used within the system being studied. The cumulative energy demand method tracks energy from the point of extraction.

Note: In this report, when a percent reduction is discussed, it is always compared to the non-use system as defined in this study, unless otherwise mentioned.

4.1.7   *Temporal Boundary*

The temporal boundary describes within what time horizon the results of the LCA are analyzed. The temporal boundary applies to inventory data and to the impact assessment. In this study, a temporal boundary of 100 years was selected because anything beyond that was judged to be too uncertain in relation to the goal of the study. This means that emissions were considered within 100 years after the residuals are used for energy or discarded. The greenhouse gas impact was also analyzed within this same 100-year time frame. When using IPCC GWPs, the greenhouse gas impact of an emission over 100 years is assumed to occur in the same year as the emissions. As a result, when using 100-year GWPs to study systems where emissions occur over time, some of the impacts associated with emissions occurring after year 1 actually occur after the 100-year period is ended.

4.2   Methodology for Additional Analyses

In addition to the life cycle analyses described above, the study also included two secondary analyses: a gate-to-gate analysis of the fate of biomass carbon, and one of the GHG emissions from the ongoing use of residuals for energy production.

4.2.1   Gate-to-Gate Analysis of Biogenic GHGs

The gate-to-gate analysis consisted of a more constrained analysis of the emissions of biogenic GHGs (mainly CO_2, CH_4, and N_2O) in isolation from any fossil fuel substitution benefits. In this analysis, the two compared systems (the biomass energy system and the non-use system) have been compared in terms of the emissions coming directly out of the units receiving the residuals (combustion units or landfills). In the case of paper recycling residuals, only their fiber fraction was considered as the focus here was on the fate of the biomass carbon. In this analysis, the system boundary for the various product systems was limited to the units receiving the residuals (i.e., "Energy Production in Forest Products Facilities" and "Alternative Fate of Biomass Residuals" in Figure 4.2 to Figure 4.4). The results were computed for two indicators described previously: differential GHGI and break-even times. A temporal boundary of 100-years was also used for that analysis.

4.2.2   GHG Emissions from Ongoing Use of Residuals for Energy Production

The analyses presented above focused on the one-time production of 1 GJ of energy (the functional unit) and looked forward in time to estimate the number of years it will take before the emissions attributable to the one-time use of biomass for energy are less than the emissions from a comparable system that disposes of the residuals. The practice of burning residuals for energy, however, is long-standing in the forest products industry. Therefore, it was also of interest to examine the net greenhouse gas impact over time attributable to the use of manufacturing residuals for energy on an ongoing basis. To look at the greenhouse gas impact from the ongoing use of biomass for energy production, a different functional unit is required. The functional unit used to assess emissions from ongoing practice is **"*The yearly production of 1 GJ of energy using biomass residuals as an ongoing practice.*"**

The definition of the temporal boundary is slightly different when analyzing the emissions attributable to ongoing practice. In fact, there are two points in time to consider. The first is the time required for the annual greenhouse gas impact from a facility using residuals for energy on an ongoing basis to equal the annual greenhouse gas impact of a facility disposing of those residuals. The second is the time it takes for the cumulative greenhouse gas impact from a facility using residuals for energy on an ongoing basis to equal the cumulative greenhouse gas impact of a facility disposing of those residuals. It takes longer for the cumulative greenhouse gas impact from the two facilities to become equal than it does for the annual greenhouse gas impact to become equal.

Data from AF&PA and NCASI were used to document the forest product industry's practices related to the use of biomass residuals for energy production.

4.3   Summary of Data Sources

North American data were used where possible and data gaps were filled using European data. The main data sources are summarized in Table 4.2.

Table 4.2 Data Sources

Process	Data Source
Direct combustion of wood residuals	NCASI, USEPA emission factors, literature
Direct combustion of WWTP residuals	Literature, NCASI
Combined heat and power from direct combustion	NCASI data
Landfilling	USEPA, NCASI
Production of energy using fossil fuels	US-EI Database* (EarthShift 2009) modified to US 2010 power grid
Transportation distances	US Census 2002 (US Department of Transportation and US Department of Commerce 2004)
Transportation processes	US-EI Database (EarthShift 2009)

* The US-EI database (EarthShift 2009) bridges the current gap in the US LCI database (National Renewable Energy Laboratory 2008) and applies US electrical conditions to the ecoinvent database (Swiss Center for Life Cycle Inventories 2010). The database includes modified processes for the 423 processes contained in the US LCI database (version 1.6) and for the 3,974 unit processes contained in the ecoinvent database (version 2.2). Specifically, for the US LCI Database, most dummy processes (processes for which no life cycle information was available) were replaced with ecoinvent proxies using US electricity. Some of the dummy processes were not replaced if they were not available in the ecoinvent data set. For the ecoinvent data set, all processes using electricity from Switzerland or one of the European regions (RER, UCTE, CENTREL or NORDEL) were indirectly adapted to instead use US electricity. This was done by rerouting data for electricity production/distribution to data for US electricity production/distribution. NCASI also updated the data for electricity production to the most recent available data. The main data sets from the US-EI database that were used in this study are documented in this report. A data set with the "WITH US ELECTRICITY" mentioned in its title was originally developed by ecoinvent, while a data set with the "NREL" mentioned in its title was originally developed by the US LCI database.

4.4   Data Quality Goals

The ISO 14044 Standard (ISO 2006b) characterizes various aspects related to data quality and data quality analysis. It lists three critical data quality requirements: time-related coverage, geographical coverage, and technology coverage. The geographic coverage for this study is related to energy produced in US forest products facilities and utilities. When feasible, the most current available data were collected, which were most frequently for 2010. For data from secondary sources (literature, databases), the most current publicly available data for North America were used. A data quality goal of this study was to depict the GHG benefits of using biomass residuals within the forest products industry in a way that is representative of current average technology across the entire industry. Data were most frequently available from the members of the American Forest and Paper Association (AF&PA) and/or NCASI. Data obtained from these members were considered representative of the broader industry. The precision of the data is discussed where appropriate.

4.5   Energy Considerations

Energy requirement calculations were made using higher heating values (HHVs). HHVs account for the total heat content of the fuel when it is burned, some of which provides useful energy to the system in which the fuel is burned and some of which is used to evaporate the water in the combustion products. The latter is generally not available for use. For life cycle purposes, HHV is a more complete method of energy accounting compared to using the lower heating value (LHV), as LHV does not account for the energy content of the fuel that was used to evaporate the water. For this reason, HHVs were used in this study.

4.6   Software Package

This modeling for this study was performed using SimaPro™ version 7.3.3 and DynCO$_2$ (Levasseur 2013).

4.7   Critical Review and Public Use of the Results

Section 5.2 of ISO 14044 (ISO 2006b, p. 28) specifies that *"when results of the LCA are to be communicated to any third party (i.e., interested party other than the commissioner or the practitioner of the study), regardless of the form of communication, a third-party report shall be prepared".* This Technical Bulletin is intended to serve as a third-party report. The Standard also specifies that *"in order to decrease the likelihood of misunderstandings or negative effects on external interested parties, a panel of interested parties shall conduct critical reviews on LCA studies where the results are intended to be used to support a comparative assertion intended to be disclosed to the public"* (ISO 2006b, p. 31). This study constitutes a comparative assertion of biomass and non-use systems. However, no formal peer review was performed, meaning that the study is not fully compliant with the ISO 14044 Standard.

5.0   DETAILED DATA SOURCES AND STUDY ASSUMPTIONS

This section describes the life cycle inventory step of the LCA, in which the typical scenarios studied are described, as are the unit processes modeled, the related system configuration scenarios, and sensitivity analyses.

5.1   Detailed Description of Unit Processes, System Configurations and Sensitivity Analyses

Table 5.1 presents an overview of the individual components that were combined into the various system configurations scenarios that were studied in this project. All possible combinations were studied, with a few exceptions that are discussed later in this section of the report, as appropriate. From these possible configurations, a typical scenario was also constructed for each of the biomass residuals studied. These are presented in Section 5.1.2.5. The next paragraphs describe in detail each of the unit processes that were involved in the various system configurations and typical scenarios.

Table 5.1 Summary of Components Used to Derive Possible System Configurations

Pre-Processing		Energy Produced at Forest Products Facilities Using Biomass Residuals		Energy Produced at Forest Products Facilities Using Fossil Fuels		Alternative Fate of Residuals	
SR0	No size reduction	SB	Heat from stoker boiler	A	Heat from natural gas	MR1	Landfill
		FB	Heat from fluidized bed	B	Heat from coal		
SR1	Size reduction	CHP1	Combined heat and power: low power to steam ratio*	C	Power from average US grid	MR2	Incineration
		CHP2	Combined heat and power: medium power to steam ratio*	D	Power from coal		
		CHP3	Combined heat and power: high power to steam ratio*	E	Power from natural gas combined cycle		

*All CHP scenarios were based on the use of a stoker boiler to produce the heat from biomass residuals. CHP configurations vary from facility to facility. In some cases, the turbines used to produce the power receive steam from all boilers of the facility (biomass and fossil fuel boilers). In other cases, they receive steam only from specific boilers (biomass or fossil fuel). Analyzing a case where the same amount of CHP would be achieved using biomass or fossil fuel boilers would have led to results that are very similar to those obtained for cases where it was assumed there was only heat produced because the only difference would have been due to energy losses in the CHP system. Therefore, in this project, a more useful CHP scenario for comparison is one where there would be CHP production only in the biomass energy system; if biomass residuals would not be used for energy production at wood products facilities, then the facility would have burned fossil fuel without CHP and would have to purchase the power from local utilities.

5.1.1   Size Reduction of Biomass Residuals

In some cases, additional size reduction is necessary before using biomass residuals for energy production. In this study, it was assumed that size reduction would <u>sometimes</u> be required for woody mill biomass residuals fuel and other similar manufacturing biomass residuals and <u>never</u> required for WWTP and paper recycling residuals.

Size reduction is typically accomplished by means of chippers, hogs, and shredders. Chippers can slice logs and mill residuals and produce chips with two surfaces and clean edges of pre-specified dimensions. Hogs (e.g., hammermills) and shredders reduce wood particles through impact force, and thus produce coarse and multi-surface particles. Hybrid size reduction equipment, such as rotary knife hogs or pan-and-disc grinders, combine the durability of hogging equipment with the sharp cutting action of chippers to produce wood chunks with cleaner edges than those produced by shredders or hogs.

A few data sets, summarized in Table 5.2, were found in the literature concerning size reduction of wood. These served as the basis for this study. More specifically, size reduction-related emissions were modeled using the US-EI database, modified with the use of diesel and electricity as presented in this table. The following US-EI data sets were used:

- **Mobile chipper:** "Wood chopping, mobile chopper, in forest/RER WITH US ELECTRICITY"; and
- **Stationary chipper:** "Industrial residual wood chopping, stationary electric chopper, at plant/RER WITH US ELECTRICITY."

Table 5.2 Various Available Data Sets for Size Reduction and Assumptions Made in This Study

Source	Operation		Diesel (L/BDmT)	Lubricants (L/BDmT)	Electricity (kWh)
Johnson et al. (2012)	Grinding of logging residuals		2.90 - 3.90	0.05 - 0.07	0
Johnson et al. (2012)	Chipping of thinnings		1.08 - 1.62	0.02 - 0.03	0
Werner et al. (2007)	Chopping of wood in mobile choppers		4.14*	0.06†	0
Werner et al. (2007)	Chopping in stationary chopper		0	0.002†	20
Jones et al. (2010)	Grinding of thinnings		1.7	N/Av.‡	0
System Configuration Scenarios and Sensitivity Analyses Considered in This Study					
SR0	No additional size reduction		0	0	0
SR1	Additional size reduction in mobile chipper	BC	2.49	0.05	0
		Low	1.08	0.02	0
		High	3.90	0.07	0
SR2	Additional size reduction in stationary chipper	BC	0	0.002	20

*Using a density of 847.31 kg/m^3 (American Petroleum Institute 2009). † Assuming a density of 900 kg/m^3. ‡Not available.

5.1.2 Energy Production Processes

5.1.2.1 Combustion of Woody Mill Residuals

Combustion of woody mill residuals is one of the unit processes that needed to be modeled to analyze the effects of producing energy using biomass residuals. Two types of boilers were modeled. First, a stoker boiler was assumed as it is the most commonly used firing method for burning woody biomass in the US forest products industry (NCASI 2011a). Stoker boiler efficiencies vary as a function of water content of the fuel. This is depicted in Figure 5.1. Sensitivity analyses were performed on water content and higher heating values. Second, to analyze the effect of the technology choice, a fluidized bed was also modeled using a single average residual water content and a single average higher heating value. Because smaller particles are required for a fluidized bed boiler, the analyses always incorporated size reduction. Table 5.3 summarizes the parameters that were varied for the modeling of manufacturing biomass residual combustion.

In addition, woody mill residuals are either used for energy production in the facility where they are generated or transported to another wood products facility. No transportation has been considered for the base case and transportation by truck over 130 km (US Department of Transportation and US Department of Commerce 2004) was modeled as a sensitivity analysis. The US-EI data set for single unit truck ("Transport, single unit truck, diesel powered NREL/US"), originally a US LCI Database data set, was used in this study.

Figure 5.1 Stoker Boiler Efficiency as a Function of Fuel Water Content (WC_R)
[Based on Kostiuk and Pfaff (1997)]

Table 5.3 Base Case and Sensitivity Analyses for Manufacturing Biomass Residual Combustion

Technology Scenario		Parameter Analyzed	Value Analyzed		Comments
SB	Stoker boiler	Water content (W_R)	BC	50% (Eff = 66%)	The range of water content for wood residuals was based on a literature review by NCASI (2011a) and assumed to be representative of the full range of wood residuals (e.g., chips, sawdust, etc.). Efficiencies were based on Forintek (Kostiuk and Pfaff 1997). According to NCASI's literature review, water content of residuals can be as high as 75%, but this is not very realistic.
			Low	10% (Eff = 79%)	
			High	60% (Eff = 60%)	
		Higher heating value (HHV)	BC	20 GJ/BDmT	The range of heating values is based on a literature review by NCASI (2011a) and is assumed to be representative of the full range of wood species (hardwood and softwood). USEPA (2009, Tables C-1 and C-2) proposed heating value for wood is 20.3 GJ/BDmT (see below for more details).
			Low	13 GJ/BDmT	
			High	26 GJ/BDmT	
FB	Fluidized bed	Water content	50% (Eff = 80%)		Efficiency for the fluidized bed was from a NCASI literature review (2011a).
		Higher heating value	20 GJ/BDmT		

The amount of residuals (Q_R) in dry tonnes required to produce a given amount of usable energy was calculated as follows:

$$Q_R = \frac{E_{DC}}{HHV \times Eff}$$

Where:

E_{DC}:   Usable energy from direct combustion (GJ);
HHV: Higher heating value (GJ HHV/BDmT); and
Eff: Boiler efficiency (%).

GHG emissions due to biomass residual combustion were modeled using emission factors from USEPA (2009, Tables C-1 and C-2), converted to physical units[7]:

- 1,807 kg BioCO$_2$[8]/BDmT;
- 0.617 kg CH$_4$/BDmT; and
- 0.0809 kg N$_2$O/BDmT.

Ashes were assumed to be disposed of in facility landfills. Landfilling of wood ashes was modeled using data from the US-EI database ("Disposal, wood ash mixture, pure, 0% water, to sanitary landfill/CH WITH US ELECTRICITY U").

5.1.2.2   *Combustion of Wastewater Residuals*

Residuals from pulp and paper mill wastewater treatment plant (WWTP) operations are often burned in mill boilers both to recover energy and for solid waste minimization. Table 5.4 presents example characteristics of WWTP residuals that can affect their suitability for combustion. From this table, it can be seen that characteristics of residuals vary significantly. In this study, sensitivity analyses for residuals combustion were set to account for this variation.

Co-firing with bark in a stoker boiler was assumed; however, only the fraction of heat from the WWTP residuals was analyzed. Burning WWTP residuals is more difficult than burning bark mainly because of their high ash and low oxygen content. To compensate for the effects of higher ash and lower oxygen contents, the moisture of the residuals must be lower to produce the same efficiency in stoker boilers (Kraft and Orender 1993). Kraft and Orender (1993) suggested that for sludge to burn like bark, the equivalent of five moisture points must be compensated for in some way. Switching from all bark to all residuals is worth five equivalent moisture points and

- co-firing 90% bark with 10% sludge is worth 0.5 moisture points; and
- co-firing 80% bark with 20% sludge is worth 1.0 moisture point.

In this study, the latter, which is more conservative, was assumed. However, as mentioned above, only the heat fraction from the residuals was analyzed. Only stoker boilers were analyzed.

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[7] Heating value and emission factors for wood and wood residuals specified by USEPA are as follows: 15.38 mmBtu HHV/short ton @12% water, 93.80 kg CO$_2$/mmBtu, 3.2E-2 kg CH$_4$/mmBtu and 4.2E-3 kg N$_2$O/mmBtu.
[8] BioCO$_2$: biogenic CO$_2$.

Table 5.4 Characteristics of WWTP Residuals

Source	WWTP Residual Type Considered	Ash Content (%wt, dry basis)	Carbon Content (%wt, dry basis)	Water Content (%wt, wet basis)	Heat Content (GJ HHV/BDmT)*
Durai-Swami et al. (1991)	Recycled paper mill and kraft mill	5.5 - 18.9	50.0 - 59.4	49.5 - 62.4	20.6 - 24.1
James and Kane (1991)	Kraft mill	8.0	48.0	60.0	19.8
Nickull et al. (1991)	Clarifier and dredged from sulfite mill	1.9	48.7	66.6	20.1
Kraft (1994), Kraft and Orender (1991, 1993)	Deinking, pulp mill, unspecified	0.2 - 48.1	28.8 - 51.8	50 - 80	5.0 - 21.5
Aghamohammadi and Durai-Swamy (1993)	Recycled paper and cardboard	2.8 - 3.0	48.4 - 48.6	50 - 85	20.6 - 20.8
Douglas et al. (1994)	Deinking	31.9 - 33.2	32.7 - 38.2	42.7 - 68.6	12.3 - 15.3
Frederik et al. (1996)	Recycled paper mill	43.8	23.2	42.0	8.38
La Fond et al. (1997)	Secondary	N/Av	49.3	N/Av	23.1
European Commission (2001), Swiss Center for Life Cycle Inventories (2010), (Hischier 2007)	Mechanical, primary and secondary Deinking	36.4 - 67.3 (deink only)	19 - 35.8	25 - 70.6	2.6 - 8.6 GJ (LHV)
NCASI (2005) taken from a memorandum to USEPA (ERG 2002)	Bleached kraft, unbleached kraft colored, deinked, mechanical, groundwood, chemi-mechanical – mixed and secondary	9.9 - 49.8	N/Av	36.2 - 80.6†	7.6 - 18.1†
USEPA GHG Reporting Rule (2009, Tables C-1 and C-2)	Wastewater from paper mills	N/Av	N/Av	N/Av	20.3§
Woodruff et al. (2012)	Pulping, deinking	10 - 60	N/Av	N/Av	9.3 - 23.3
NCASI unpublished lab experiments	Bleached kraft combined, deinking combined, non-integrated combined, non-integrated primary, deinking primary	26.1 - 74.4	23.1 - 37.3	N/Av	N/Av

*When unknown, assumed to be HHV. †Includes dewatered and not dewatered residuals. ‡Assuming USEPA values are expressed in Btu HHV/lb. §According to USEPA, wood residuals means materials recovered from three principal sources: municipal solid waste (MSW); construction and demolition debris; and primary timber processing. Wood residuals recovered from MSW include wooden furniture, cabinets, pallets and containers, scrap lumber (from sources other than construction and demolition activities), and urban tree and landscape residuals. Wood residuals from construction and demolition debris originate from the construction, repair, remodeling and demolition of houses and non-residential structures. Wood residuals from primary timber processing include bark, sawmill slabs and edgings, sawdust, and peeler log cores. Other sources of wood residuals include, but are not limited to, railroad ties, telephone and utility poles, pier and dock timbers, wastewater process sludge from paper mills, trim, sander dust, and sawdust from wood products manufacturing (including resinated wood products residuals), and logging residuals.

Water content of WWTP residuals (primary and secondary treatment, deinking residuals) can vary widely; see Table 5.4. Residuals are typically mechanically dewatered. The general objective of dewatering is to remove water to the extent that the solids volume is reduced and the resulting residuals behave as a solid and not as a liquid. Residuals dewatering is accomplished at pulp and paper facilities by incorporating equipment and practices that result in increased WWTP residuals solids content. Employing residuals dewatering a) reduces the costs associated with residuals hauling, b) maximizes the use of remaining landfill capacity, c) makes residuals a more attractive fuel for combination fuel-fired boilers, and d) makes residuals more attractive for beneficial use opportunities (NCASI 2008). WWTP residuals can be dewatered using several technologies, of which belt filter presses and screw presses are the most frequently used in the US industry (NCASI 2008). Solids contents achievable using belt filter and screw presses are over 30% ($WC_R < 70\%$[9]) and 40% ($WC_R < 60\%$), respectively.

In this study, it was assumed that WWTP residuals were dewatered to 40% solids content, whether they were to be burned or landfilled, i.e., dewatering is assumed to happen both in the biomass and non-use systems. For this reason, dewatering was not included in the study. Ashes from residuals combustion were assumed to be landfilled on site. Landfilling of sludge ashes was modeled using the US-EI database (Disposal, wood ash mixture, pure, 0% water, to sanitary landfill/CH WITH US ELECTRICITY), assuming landfilling of wood ash could be taken as a proxy. Sensitivity analyses were performed on water content, heating value, and ash content. These are summarized in Table 5.5. Efficiencies have been derived from Figure 5.1 (assuming $WC_{WR} + 1\%$).

Table 5.5 Scenarios/Sensitivity Analyses for WWTP Residual Combustion

Parameter Analyzed		Value Analyzed
Water content (WC_R)	BC	60% (Eff =60%)
	Low	50% (Eff =66%)
	High	70% (Eff =53%)
Higher heating value (HHV)	BC	15 GJ/BDmT
	Low	10 GJ/BDmT
	High	20 GJ/BDmT
Ash content	BC	30%
	Low	10%
	High	50%

According to USEPA (2009) emission factors for wood and wood residuals should be used for WWTP sludge. However, the carbon content of WWTP residuals can vary significantly depending on the type of residuals. In this study, USEPA emission factors are used as a base case and sensitivity analyses are performed accommodate the variability in the carbon content of WWTP residuals. This is summarized in Table 5.6. It is also assumed that the higher carbon contents are associated with the higher HHVs.

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[9] WC_{WWTPR}: water content of WWTP residuals.

Table 5.6 Emission Factors for Burning WWTP Residuals

Parameter Analyzed			Value Analyzed
Biogenic CO_2	kg CO_2/BDmT	BC	1,807 (USEPA, CC = 49%)
		Low	697 (CC = 19%)
		High	2017 (CC = 55%)
CH_4	kg CH_4/BDmT	BC	0.617 (USEPA)
N_2O	kg N_2O/BDmT	BC	0.0809 (USEPA)

5.1.2.3   *Combustion of Paper Recycling Residuals (OCC Rejects)*

Paper recycling residuals, and more specifically OCC rejects, are often burned in boilers at pulp and paper mills that process recovered paper. This is done both for volume reduction and for energy recovery. Table 5.7 presents some general characteristics of OCC rejects, as well as the assumptions that were made in this study. OCC rejects were considered representative of the broader paper recycling residuals category. Ranges provided in the table are based on typical characteristics at a number of mills. They are intended to capture the breadth of anticipated variation for these materials.

Paper recycling residuals are a mix of fiber and plastic. In a stoker boiler, the fiber fraction is likely to behave as WWTP residuals (lower efficiency than that for wood biomass residuals). The plastic fraction is likely to behave like a fossil fuel (higher efficiency than that for woody biomass residuals). In this study, it was assumed that the boiler efficiency would be the same as that for woody biomass residuals at similar water content. Only stoker boilers were analyzed.

Ashes from residuals combustion were assumed to be landfilled on site. Landfilling of paper recycling residuals ashes was modeled using the US-EI database (Disposal, wood ash mixture, pure, 0% water, to sanitary landfill/CH WITH US ELECTRICITY), under the assumption that landfilling of wood ash could be taken as a proxy.

Table 5.7 General Characteristics of OCC Rejects and Sensitivity Analyses

Parameter		Range	Source	Range Analyzed in This Study		
				BC	Low	High
Fiber	% dry wt.	30 - 95	NCASI (2000)	60	30	90
Plastics	% dry wt.	5 - 70	NCASI (2000)	40	10	70
Ashes	% dry wt.	1 - 10	NCASI (2000)	5		
Biogenic CO_2 emissions when burning fiber fraction of OCC	kg CO_2/kg fiber	1.807*-1.833†	(2009, Tables C-1 and C-2)	1.807	N/A	N/A
CH_4 emissions when burning fiber fraction of OCC	kg CH_4/kg fiber		Estimated*	6.17E-5*		
N_2O emissions when burning fiber fraction of OCC	kg N_2O/kg fiber		Estimated*	8.09-6*		
Fossil CO_2 emissions when burning plastic fraction	kg CO_2/kg plastic	2.30	US-EI (EarthShift 2009)‡	2.30		
CH_4 emissions when burning plastic fraction of OCC	kg CH_4/kg plastic	6.38E-6	US-EI (EarthShift 2009)‡	6.38E-6		
N_2O emissions when burning plastic fraction of OCC	kg N_2O/kg plastic	2.58E-5	US-EI (EarthShift 2009)‡	2.58E-5		
Higher heating value	GJ HHV/BDmT	18.8-27.7	NCASI (2000)	Fiber fraction: 19.1 Plastic fraction: 40.9		
Water content (boiler efficiency)	% wet wt. (%)	40-70	NCASI (2000)	55 (63)	40 (71)	70 (54)

* USEPA (2009) emission factors for wood and wood residuals, expressed based in physical units, are used for the fiber fraction of OCC rejects. † Assuming all carbon emitted as CO_2. ‡Disposal, plastics, mixture, 15.3% water, to municipal incineration/CH WITH US ELECTRICITY.

The carbon dioxide produced when plastics are burned is commonly accounted for using the same methods as for carbon dioxide produced in burning fossil fuels [USEPA 2010, Table C-1 and Section 98.33(e)]. For the gate-to-gate analyses of the biogenic GHG releases, it is only the accounting methods for biogenic carbon that are in question. For this reason, for these analyses, only the fiber fraction of paper recycling residuals was considered.

The heating values of the individual plastic and fiber fractions were presented in Table 5.7. There is no available information for the individual water contents of each of the fractions. However, it was shown in Table 5.7 that water content of paper recycling residuals varies significantly and it can be assumed that, while the plastic fraction of the residuals may contain some water, most of it would be found in the in the fiber fraction. In this analysis, the same water content as paper recycling residuals was applied to its fiber fraction. This resulted in 66% water for base case condition, which is very similar to WWTP residuals.

5.1.2.4   *Combined Heat and Power (CHP)*

In this study, a hypothetical combined heat and power configuration (CHP) representative of those commonly used in the forest products industry was modeled. This system, depicted in Figure 5.2, consisted of a biomass-fired boiler with high pressure steam routed to a back pressure turbine.

$$E_{DC} = S_{HP} + E_{Turb} = S_{HP} + S_{MP/LP} + P + L$$

$$S_{HP} + S_{MP/LP} + P = 1 \; GJ$$

Legend:
Q_R: Quantity of wood residues, E_{DC}: Usable energy from direct combustion,
E_{Turb}: Steam to turbine, S_{HP}: High pressure steam to process,
$S_{MP/LP}$: Extraction steam to process, **P**: Power, and **L**: Losses

Figure 5.2 Hypothetical CHP Configuration Considered in This Study

The relationship between Q_R and E_{DC} is described above in Section 5.1.2.1. Three scenarios were considered: 1) one representing an older pulp and paper mill (CHP1), 2) one representing a newer pulp and paper mill (CHP2), and 3) one considering the maximum power production through use of a condensing turbine. This last scenario could be considered representative of cases where very little steam is required. All three scenarios are presented in Table 5.8.

All the CHP scenarios were performed with base case stoker boiler conditions.

Table 5.8 CHP Scenarios

Scenario #	E_{DC}	E_{Turb}	S_{HP}	P	$S_{MP/LP}$	$S_{HP}+S_{MP/LP}$	L
				(GJ)			
CHP1	1.0499	0.9974	0.05 E_{DC} = 0.0525	0.18 E_{Turb} = 0.1795	0.77 E_{Turb} = 0.7680	0.8205	0.05 E_{Turb} = 0.0499*
CHP2	1.0499	0.9974	0.05 E_{DC} = 0.0525	0.29 E_{Turb} = 0.2892	0.66 E_{Turb} = 0.6583	0.7108	0.05 E_{Turb} = 0.0499*
CHP3	1.0499	0.9974	0.05 E_{DC} = 0.0525	0.95 E_{Turb} = 0.9475	0	0.0525	0.05 E_{Turb} = 0.0499*

* Used for sootblowing.

5.1.2.5   *Energy Production Using Fossil Fuels*

Two possible options for producing energy from biomass residuals were considered: heat and combined heat and power. This means that an equivalent system needed to be studied regarding fossil fuels. For cases where the biomass energy system included heat production at the forest products facility, it was assumed that in the fossil fuel-based system an equivalent quantity of heat would be produced at the facility using either coal (A) or natural gas (B).

A somewhat different approach was taken for cases where combined heat and power would be applied to the biomass energy system. CHP configurations vary from facility to facility. In some cases, the turbines used to produce power receive steam from all boilers at the facility (i.e., both biomass and fossil fuel boilers). In other cases, they receive steam only from specific boilers (biomass or fossil fuel). Analyzing a case where the same amount of CHP would be achieved using biomass or fossil fuel boilers would have led to results that are very similar to those that were obtained for the case where it was assumed there was only heat produced because the only difference would have been due to energy losses in the CHP system, which are typically very small. Therefore, in this project, a more useful CHP scenario for comparison is one where there would be CHP production only in the biomass energy system; if biomass residuals were not used for energy production at forest products facilities, then the facility would have burned fossil fuel without CHP and would have to purchase the power from local utilities. Three scenarios were analyzed: C) US average electrical grid mix, D) power generated using coal, and E) power generated using natural gas combined cycle. These scenarios were selected in order to cover a large spectrum of possible mill situations.

All energy production processes from fossil fuel-related processes were modeled using the US-EI database. In specific, the following data sets were used for heat production:

- **Heat from coal:** "Bituminous coal, combusted in industrial boiler NREL/US" (this data set includes transportation of the coal to the boiler); and
- **Heat from natural gas:** "Natural gas, combusted in industrial boiler NREL/US" (this data set includes transportation of the natural gas to the boiler).

Both these data sets are expressed based on the quantity of fuel burned and not on the quantity of energy produced. To calculate the energy produced, the following was assumed (U.S. EPA 2009, Tables C-1):

- **Coal:** boiler efficiency of 85% and higher heating value of 24.93 MMBtu per short ton (29.0 GJ/tonne); and
- **Natural gas:** boiler efficiency of 80% and HHV of 1.028E-3 MMBtu per cubic feet (0.0383 GJ/m^3).

The following data sets were used for electricity production at utilities:

- Electricity, bituminous coal, at power plant NREL/US; and
- Electricity, natural gas, at turbine, 10MW/GLO WITH US ELECTRICITY.

The US average consumption grid mix was also modeled using processes from the US-EI Database. It was calculated by considering the quantity of power produced in the US by type of fuel, the quantity of power exported, and the quantity imported from Canada and Mexico. The production mix for the United States was calculated using 2010 data from the US Department of Energy, Energy Information Administration (EIA 2012, Forms EIA-906, EIA-920 and EIA-923). Data for 2009 from the International Energy Agency were used for Mexico (IEA 2013), as these were the most recently available. Since electricity imports from Mexico represent less than 3% of the total energy consumed in the US, these data are not expected to have a significant effect on the results. Canadian data were taken from Statistics Canada (2013a, b, c). Table 5.9 presents the fuel mix for US average electricity consumption as well as the US-EI data sets that were used to model it.

Table 5.9 US Average Electricity Grid Fuel Consumption Mix

Fuel Type	%	US-EI Data Set Used
Coal (including CHP)	45	Electricity, bituminous coal, at power plant NREL/US
Petroleum	1	Electricity, residual fuel oil, at power plant NREL/US
Natural gas (including CHP)	24	Electricity, natural gas, at power plant NREL/US
Nuclear	20	Electricity, nuclear, at power plant NREL/US
Hydroelectric	7	Electricity, hydropower, at power plant/SE WITH US ELECTRICITY U (89%), and Electricity, hydropower, at pumped storage power plant/US WITH US ELECTRICITY U (11%)
Wind	2	Electricity, at wind power plant/RER WITH US ELECTRICITY
Wood and wood derived fuels (CHP)	1	Electricity, biomass, at power plant NREL/US

Note that this US average grid mix was also used for the background electricity consumption of all processes modeled with the US-EI database.

Different fuels may be associated with different energy requirements for air emissions control of combustion units. In this study, it was assumed that the differences in energy requirements for emissions control were insignificant compared to the energy produced by the combustion units. This assumption was tested using sensitivity analyses.

5.1.3   Alternative Fates

5.1.3.1   *Landfilling of Woody Mill Residuals*

In landfills, a fraction of the biogenic carbon in forest products decays, primarily into gas. The remaining fraction is non-degradable under anaerobic conditions. This latter fraction varies by type of product. The degradable fraction of the biogenic carbon in landfills was assumed to decay according to a first order decay equation, with a variable rate constant, as presented in Table 5.10. Under anaerobic conditions, about one-half of the carbon is converted to biogenic CO_2 while the other half is converted to CH_4. Under aerobic conditions (e.g., in shallow unmanaged landfills), a much smaller fraction of the gas consists of CH_4. The methane correction factor, provided in Table 5.10, is used to adjust methane generation to reflect the extent of anaerobic conditions in different types of landfills.

Another important factor influencing the releases of landfill CO_2 and CH_4 methane to the atmosphere is the extent to which CH_4 is oxidized to biogenic CO_2 before exiting the landfill. Even in the absence of systems designed to capture and destroy methane, about 10% of the methane is oxidized as it moves through the surface layers of the landfill. Finally, some landfills are equipped with cover systems to collect and destroy methane by burning, and assumptions need to be made regarding the fraction of the methane that is collected and burned. It this study, it was assumed that wood residuals would be landfilled in an on-site mill landfill (i.e., no transportation required) and that for these mill landfills there was no methane capture, assumptions consistent with current practice in the industry.

Landfill parameters analyzed in this study are presented in Table 5.10.

Table 5.10 Parameters Affecting Emissions from Landfilling of Woody Mill Residuals

Parameter Analyzed	Value Analyzed		Source(s)
Biogenic carbon content (CC)	BC	50%	IPCC (IPCC 2006b)
Non-degradable carbon under anaerobic conditions (F_{CCND})	BC	55%	Wang et al. (2011)
	Low	45%	
	High	65%	
Decay rate (k)	BC	0.038 yr^{-1}	USEPA (2012), value representative of 52 US municipal solid waste landfills and various precipitation conditions
	Low	0.020 yr^{-1}	
	High	0.057 yr^{-1}	
Methane correction factor (MCF)	BC	1	IPCC (2006a), methane correction factors set up to be representative of managed anaerobic
Fraction of methane oxidized in landfill covers (F_{CH4OX})	BC	10%	IPCC (2006a)
Fraction of methane burned or oxidized (F_{CH4CB})	BC	0%	Assuming no mill landfill is equipped with methane collection systems

Cumulative quantities of carbon dioxide and methane emitted at a given time are calculated as follows.

Quantity of Carbon Converted to Gas at a Given Time:

$$Q_{C \rightarrow Gas} = Q_R\left(1 - e^{-kt}\right) \times MCF \times CC \times \left(1 - F_{CCND}\right)$$

Where Q_R is the quantity of residuals required to produce a given amount of usable energy in the biomass product system and t the time in years.

Quantity of Carbon Converted to Methane ($Q_{C \rightarrow CH4}$):

$$Q_{C \rightarrow CH4} = Q_{C \rightarrow Gas} \times 0.5$$

Quantity of Methane Not Collected and Burned (Q_{CH4NCB})

$$Q_{CH4NCB} = Q_{C \rightarrow CH4} \times \left(1 - F_{CH4CB}\right)$$

Quantity of Methane Released to the Environment ($Q_{CH4,Landfill}$):

$$Q_{CH4,Landfill} = Q_{CH4NCB} \times \left(1 - F_{CH4OX}\right) \times \frac{16}{12}$$

Quantity of Carbon Dioxide Released to the Environment ($Q_{CO2,Landfill}$):

$$Q_{CO2,Landfill} = \left(Q_{C \rightarrow Gas} - Q_{CH4,landfill} \times \frac{12}{16} \right) \times \frac{44}{12}$$

Other environmental loads related to landfilling activities were modeled using the US-EI database (Disposal, wood untreated, 20% water, to sanitary landfill/CH WITH US ELECTRICITY).

5.1.3.2 *Incineration of Woody Mill Residuals*

Incinerating the woody mill residuals without recovering the energy is not a very likely fate for these residuals. However, it was still modeled in this study as a way to illustrate the simplest way by which biogenic carbon can return to the atmosphere. Emissions from incineration are assumed the same as those for combustion for energy generation (see Section 5.1.2).

5.1.3.3 *Landfilling of WWTP Residuals*

Assumptions made to model GHG emissions from landfilling WWTP residuals are summarized in Table 5.11. Detailed calculations were presented in Section 5.1.3.1. Other environmental loads from landfilling of WWTP residuals were modeled using the US-EI database (Disposal, sludge from pulp and paper production, 25% water, to sanitary landfill/CH WITH US ELECTRICITY).

Table 5.11 Parameters Affecting Emissions from Landfilling of WWTP Residuals

Parameter Analyzed	Value Analyzed		Source(s)
Biogenic carbon content (CC)	BC	49%	See Table 5.5.
	Low	19%	
	High	55%	
Non-degradable carbon under anaerobic conditions (F_{CCND})	BC	50%	From NCASI unpublished experiments
	Low	40%	
	High	60%	
Decay rate (k)	BC	0.038	USEPA (2012), value representative of 52 US municipal solid waste landfills and various precipitation conditions
	Low	0.020	
	High	0.057	
Methane correction factor (MCF)	BC	1	IPCC (2006a), methane correction factors set up to be representative of managed anaerobic
Fraction of methane oxidized in landfill covers (F_{CH4OX})	BC	10%	IPCC (2006a)
Fraction of methane burned or oxidized (F_{CH4CB})	BC	0%	Assuming no mill landfill is equipped with methane collection systems

5.1.3.4 *Incineration of WWTP Residuals*

Emissions from incineration are assumed to be the same as those related to combustion for energy generation (see Section 5.1.2.2).

5.1.3.5   Landfilling of Paper Recycling Residuals

Assumptions made to model GHG emissions from landfilling the fiber fraction of OCC rejects are summarized in Table 5.12. Detailed equations were provided in Section 5.1.3.1. Other environmental emissions related to the use of resources for landfilling the fiber fraction, as well as for landfilling the plastic fraction of OCC rejects, were modeled using the US-EI database:

- **Fiber fraction of residuals:** Disposal, sludge from pulp and paper production, 25% water, to sanitary landfill/CH WITH US ELECTRICITY, assuming WWTP residuals are representative of the fiber fraction of the paper recycling residuals, and
- **Plastic fraction of residuals:** Disposal, paper, 11.2% water, to sanitary landfill/CH WITH US ELECTRICITY.

Table 5.12 Parameters Affecting Emissions from Landfilling the Fiber Fraction of OCC Rejects

Parameter Analyzed	Value Analyzed		Source(s)
Biogenic carbon content (CC)	BC	50%	IPCC (2006a)
Non-degradable carbon under anaerobic conditions (F_{CCND})	BC	61%	NCASI (2004)
	Low	40%	
Decay rate (k)	BC	0.038	USEPA (2012), value representative of 52 US municipal solid waste landfills and various precipitation conditions
	Low	0.020	
	High	0.057	
Methane correction factor (MCF)	BC	1	IPCC (2006a), methane correction factors set up to be representative of managed anaerobic
Fraction of methane oxidized in landfill covers (F_{CH4OX})	BC	10%	IPCC (2006a), assuming no mill landfill is equipped with methane collection systems
Fraction of methane burned or oxidized (F_{CH4CB})	BC	0%	Assuming no mill landfill is equipped with a methane collection system

5.1.3.6   Incineration of Paper Recycling Residuals

Emissions from the incineration of paper recycling residuals were assumed to be the same as those related to combustion for energy generation (see Section 5.1.2.3).

5.2   Definition of Typical Scenarios

5.2.1   Current Energy Use and Waste Management Practices at Forest Products Facilities

Energy production and waste management data were compiled for the US forest products facilities (both pulp and paper and wood products) using data collected by AF&PA, NCASI, and the American Wood Council (AWC) and are summarized in Table 5.13 and Table 5.14. Most data are from 2010. Waste management data for the wood products facilities were compiled through 2008, only. For this reason, to produce a representative number for the entire forest products industry in 2010, the ratio of management options in 2008 was applied to 2010 production data. There are no "waste management"

data available for bark, sawdust and similar woody mill residuals produced at pulp and paper facilities, as they are not a waste but rather almost always being burned for energy.

Table 5.13 US Forest Products Facilities Estimated Fuel Mix
(Not Including Purchased Power and Steam)

Fuel Type	Paper Products Facilities	Wood Products Facilities	Forest Products Industry (AF&PA, NCASI and AWC members used as a proxy for the entire US industry)
			%
Biomass fuels	**70.9**	**90.1**	**72.1**
Fossil fuels	**29.1**	**9.9**	**27.9**
Natural gas	13.9%	8.6%	13.5%
Coal	10.9%	0.3%	10.2%
Other fossil	4.4%	0.9%	4.1%
Power produced through combined heat and power	GJ/GJ fuel input	0.06	

Table 5.14 Waste Management Practices at US Forest Products Facilities

Waste Type	% Beneficial Use	Disposal		
		Total	% Landfill (% of disposal)	% Burning* (% of disposal)
Paper Products Facilities				
WWTP residuals	32.5%	67.5%	44.4% (65.8%)	23.1% (34.2%)
All others (causticizing wastes, general mill trash, construction debris, OCC rejects, landfilled broke, bark, wood residual, sawdust, knots, metal and other recyclable)	26.9%	73.1%	68.4% (93.6%)	4.7% (6.4%)
Wood Products Facilities				
All waste types (incl.: unusable sawdust, shavings, bark, garbage, recyclables, used oil, pallets, etc.)	96.2%	3.8%	3.8% (100%)	Negligible
Forest Products Industry (AF&PA and NCASI members used as a proxy for the whole US industry)				
Other waste from pulp and paper facilities and all waste from wood products facilities	57.8%	42.2%	39.6% (93.8%)	2.6% (6.2%)

*This does not include burning for energy.

Typical scenarios were modeled to be as representative as possible of current practices within US forest products manufacturing facilities using the information in the tables above. In addition, all parameters were set to their base case values for typical scenarios.

5.2.2 Woody Mill Residuals

The typical scenario considered for woody mill residuals is summarized in Table 5.15. A stoker boiler was assumed in the typical scenario as it is the most commonly used firing method for burning woody biomass (NCASI 2011a). Size reduction is sometimes required to process oversized particles prior to

burning. Stoker boilers can be used to burn biomass residuals for a broad spectrum of sizes (NCASI 2011a). Woody mill residuals are generally found in sizes suitable for stoker boilers (NCASI 2011a). For this reason, as a typical scenario, no size reduction was considered. The ratio of steam to power produced was set based on industry data for CHP (from AF&PA, NCASI, and AWC). This study analyzed only cases where CHP would be produced using biomass boilers and not fossil fuel boilers. Therefore, it was assumed that, at the industry level, the total power produced from CHP would be generated from biomass and fossil fuels in forest products facilities in the same ratio as overall fuel usage, and only the fraction from biomass was considered (5%). Turbine efficiency assumed for the CHP1 scenario above was assumed for the typical scenario as a conservative assumption. The actual heat/CHP configuration assumed for this system is depicted in Figure 5.3.

Figure 5.3 Heat/CHP Configuration Considered in the Typical Scenario for Woody Mill Residuals

The typical scenario considered was based on the data presented earlier in Table 5.13 for the entire forest products industry. It can be seen from this table than natural gas and coal are the main fossil fuels used by the US forest products industry. Therefore, in the typical scenario, only those two were considered in the ratio used by the industry. It was hence assumed that 57% of the steam produced from biomass would displace heat from natural gas and 43% would displace heat from coal. All (100%) of the displaced power was assumed to be from the US power consumption grid mix average. As shown previously in Table 5.14, when woody mill residuals are disposed of, they are either landfilled (94%) or burned (6%). However, as the burning reported by NCASI/AF&PA members most likely involves recovery of energy, this was not considered to be an alternative fate for the typical scenario. Instead, 100% landfilling was considered. It should be noted however, that there are very few data on what would be a reasonable "typical" alternative fate for woody mill residuals as it is not a common practice of the industry to dispose of these.

Table 5.15 Typical Scenario for Woody Mill Residuals

Pre-Processing			Energy Produced at Forest Products Facilities Using Biomass Residuals		Energy Produced at Forest Products Facilities or Utilities Using Fossil Fuels			Alternative Fate of Residuals		
SR0	No size reduction	100%	Heat from stoker boiler and residual steam from CHP	92%	Natural gas	57%	MR1	Landfill	100%	
					Coal	43%				
SR1	Size reduction - Mobile chipper	0%	Power from CHP	8%	US average power consumption mix	100%	MR2	Incineration	0%	
SR2	Size reduction - Stationary chipper	0%								

5.2.3 WWTP Residuals

The typical scenario considered for WWTP residuals is summarized in Table 5.16. A stoker boiler was also assumed in the typical scenario as a conservative assumption. The ratio of steam to power produced was set based on industry data (from AF&PA, NCASI, and AWC) regarding CHP. This study analyzed only cases where CHP would be produced using biomass boilers and not fossil fuel boilers. Therefore, it was assumed that, at the industry level, the total power produced from CHP would be generated from biomass and fossil fuels in forest products facilities in the same ratio as overall fuel usage and only the fraction from biomass was considered (5%). Turbine efficiency assumed for the CHP1 scenario above was used for the typical scenario as a conservative assumption. The actual heat/CHP configuration assumed for this system is depicted below in Figure 5.4.

Figure 5.4 Heat/CHP Configuration Considered in the Typical Scenario for WWTP Residuals
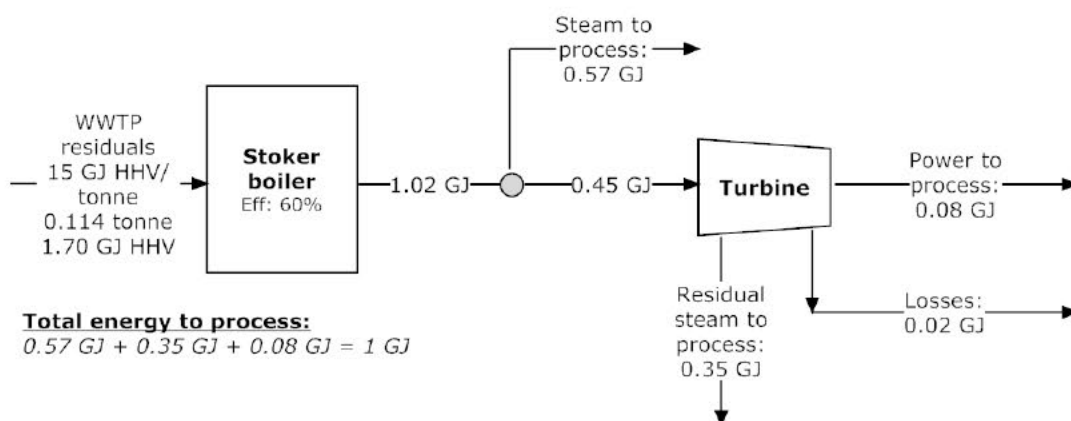
The typical scenario considered was based on the data presented in Table 5.13 for the whole industry. It can be seen from this table that natural gas and coal are the main fossil fuels used by the US forest products industry. In the typical scenario, therefore, only these two fuels were considered in the ratio used by the industry. It was hence assumed that 57% of the steam produced from biomass would

displace heat from natural gas and 43% would displace heat from coal. All (100%) of the displaced power was assumed to be from the US power consumption grid mix average. Finally, as shown previously in Table 5.14, WWTP residuals that are not beneficially used are typically landfilled (66%) or burned (34%). As it is not necessary that burning residuals would involve recovery of energy (for instance, in cases where the heating value would be too low), this ratio was assumed in the typical scenario.

Table 5.16 Typical Scenario for WWTP Residuals

Energy Produced at Forest Products Facilities Using Biomass Residuals		Energy Produced at Forest Products Facilities or Utilities Using Fossil Fuels		Alternative Fate of Residuals		
Heat from stoker boiler and residual steam form CHP	92%	Natural gas	57%	MR1	Landfill	66%
		Coal	43%			
Power from CHP	8%	US average power consumption mix	100%	MR2	Incineration	34%

5.2.4 Paper Recycling Residuals

The typical scenario considered for paper recycling residuals is summarized in Table 5.17. A stoker boiler was assumed in the typical scenario as a conservative assumption. The ratio of steam to power produced was set based on industry data (from AF&PA, NCASI, and AWC) for CHP. This study analyzed only cases where CHP would be produced using biomass boilers and not fossil fuels boilers. Therefore, it was assumed that, at the industry level, the total power produced from CHP would be generated from biomass and fossil fuels in forest products facilities in the same ratio as overall fuel usage and only the fraction from biomass was considered (5%). Turbine efficiency assumed for the CHP1 scenario above was used for the typical scenario as a conservative assumption. The actual heat/CHP configuration assumed for this system is depicted below in Figure 5.5.

Figure 5.5 Heat/CHP Configuration Considered in the Typical Scenario
for Paper Recycling Residuals

The typical scenario considered was based on the data presented above in Table 5.13 for the whole industry. It can be seen from this table than natural gas and coal are the main fossil fuels used by the US forest products industry. In the typical scenario, only those two were considered in the ratio used by the industry. It was hence assumed th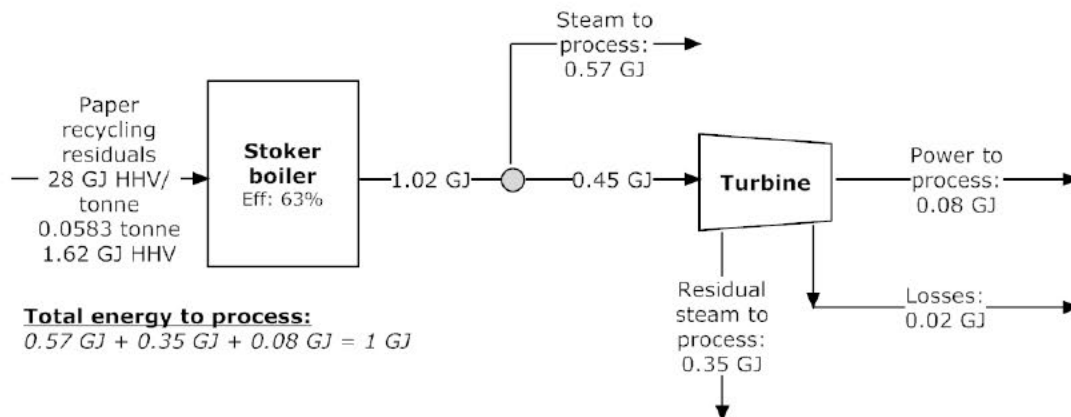at 57% of the steam produced from biomass would displace heat from natural gas and 43% would displace heat from coal. All (100%) of the displaced power was

assumed to be from the US power consumption mix average. Finally, as shown in Table 5.14, paper recycling residuals that are not beneficially used are typically landfilled (93.6%) or burned (6.4%). As it is not necessary that burning residuals would involve recovery of energy (for instance if they were disposed of in municipal facilities), this ratio was assumed in the typical scenario.

Table 5.17 Typical Scenario for Paper Recycling Residuals

Energy Produced at Forest Products Facilities Using Biomass Residuals		Energy Produced at Forest Products Facilities Or Utilities Using Fossil Fuels		Alternative Fate of Residuals		
Heat from stoker boiler and residual steam form CHP	92%	Natural gas	57%	MR1	Landfill	93.6%
		Coal	43%			
Power from CHP	8%	US average power consumption mix	100%	MR2	Incineration	6.4%

6.0   RESULTS AND DISCUSSION: CRADLE-TO-FINAL ENERGY

This section discusses the results of the cradle-to-final energy analysis, i.e., including fossil fuel substitution.

Note: For the GHGIs indicators, the results at 100 years of applying the dynamic carbon footprinting approach are compared with those obtained using the IPCC 100-year GWPs. Because the comparisons reveal that the differences at 100 years are small, for simplicity, the contribution, scenarios, and sensitivity analyses results are presented using only 100-year GWPs.

6.1   Woody Mill Residuals

This section presents the results for the woody mill residuals.

6.1.1   Typical Scenario: Base Case Results

The typical scenario was first analyzed with all parameters at their base case values.

6.1.1.1   *Greenhouse Gas Impact: Differential GHGI*

When using the dynamic carbon footprinting approach, the biomass energy system produces, after 100 years, a greenhouse gas impact that is **261 kg CO₂E lower**[10] per gigajoule of energy produced compared to the defined non-use system. This reduction is **254 kg CO₂E** when applying IPCC 100-year GWPs.

Figure 6.1 presents the 100-year differential GHGI for the biomass energy system compared to the non-use system as well as the contribution of each system component to the results using IPCC 100-year GWPs. In this figure,

- the GHGI indicator results from the non-biogenic CO_2 releases [which include fossil fuel-related CO_2, CH_4 and N_2O as well as biomass-related CH_4 and N_2O and all other GHGs

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[10] Results in this report are always presented as differences (i.e., biomass energy system minus non-use system). The "Relative GHGI" indicator does not include biogenic CO_2. The "Differential GHGI" indicator includes emissions and removals of biogenic CO_2.

       (fossil fuel- and biomass-related)], the GHGI indicator results from biogenic CO_2 releases and the total GHG releases[11] are depicted separately;
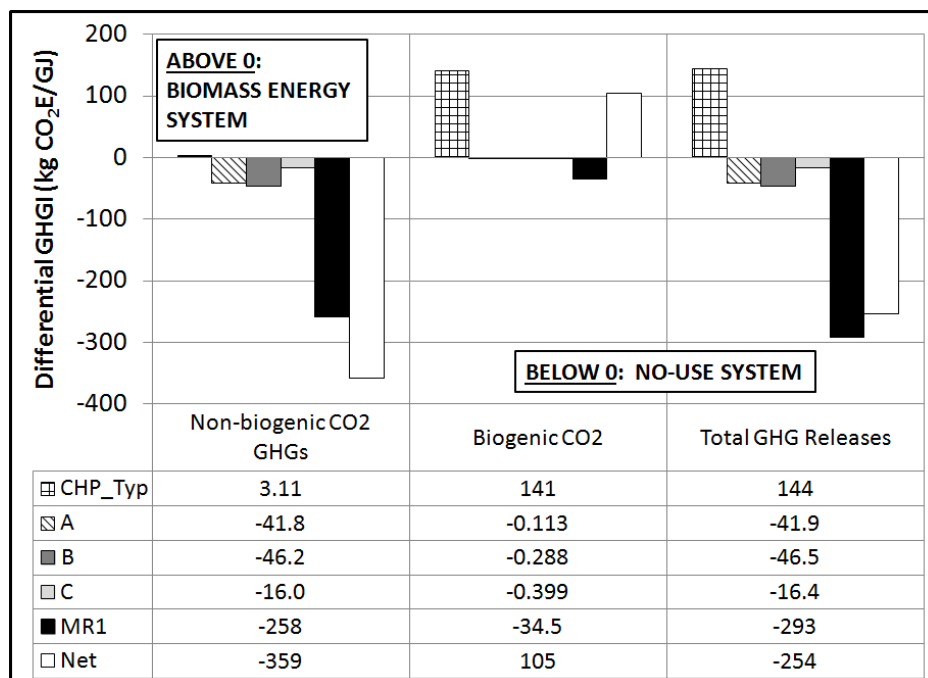
- the results from the biomass energy system are shown as positive numbers;
- the results from the non-use system are shown as negative numbers (because they are avoided);
- the "net" bars represent the sum of the different system components; and
- a net positive indicates that the biomass energy system impacts are greater than the non-use system and a net negative indicates that the biomass energy system impacts are lower than the non-use system (in other words, the more net negative the indicator result, the more beneficial is the biomass energy system).

As shown in this figure, most of the difference between the biomass energy and non-use systems is attributable to non-biogenic CO_2 GHGs. More specifically, the methane emissions from landfills (most of MR1) avoided when burning residuals to produce energy is responsible for a large portion of the benefits from the biomass energy system. Reducing energy production from fossil fuels [i.e., heat from coal (A), heat from natural gas (B), and US average power grid (C)] also contributes to the difference, but to a lesser extent. The greenhouse gas impact caused by the emissions of biogenic CO_2 are different in the two systems (i.e., the net is not zero) for two reasons. First, much of the biogenic carbon is released as methane in the non-use system (included within non-biogenic CO_2 GHGs) and mostly as carbon dioxide in the biomass energy system. Second, some of the carbon is stored in landfills in the non-use system.

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[11] In this report, "Total GHG releases" is used as a short form for the sum of non-biogenic CO_2 GHGs and biogenic CO_2 GHGs.

	Non-biogenic CO_2 GHGs	Biogenic CO_2	Total GHG Releases
⊞ CHP_Typ	3.11	141	144
⊠ A	-41.8	-0.113	-41.9
▨ B	-46.2	-0.288	-46.5
☐ C	-16.0	-0.399	-16.4
■ MR1	-258	-34.5	-293
☐ Net	-359	105	-254

Figure 6.1. Contribution Analysis for the Differential GHGI (at 100 Years) for Woody Mill Residuals - Typical Scenario
[In the figure, the different components of the biomass energy system are depicted as follows: CHP system as described in Figure 5.3 (CHP_Typ). The components of the non-use system are depicted as follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residuals in landfills (MR1). Results reflect the use of 100-year GWPs.]

6.1.1.2   *Greenhouse Gas Impact: Relative Non-BioCO₂ GHGI*

The result for the "Relative Non-BioCO$_2$ GHGs" indicator is -99.1%[12] for both the dynamic carbon footprinting approach and IPCC 100-year GWPs, meaning that the biomass product system generates almost no GHGs when ignoring biogenic CO_2.
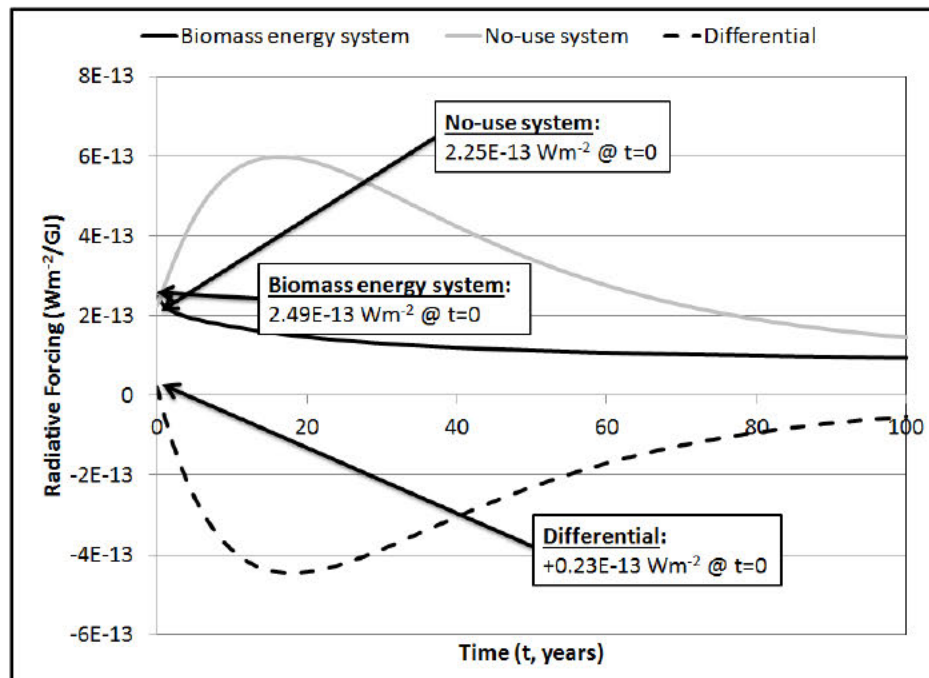
6.1.1.3   *Greenhouse Gases: Timing of Impacts*

When residuals are burned for energy, the biogenic carbon is immediately released to the atmosphere. In contrast, residuals placed into landfills degrade relatively slowly, releasing the carbon (both CO_2 and CH_4) over time.

Figure 6.2 shows the annual radiative forcing attributable to greenhouse gas emissions from producing 1 GJ of energy in the biomass energy and non-use systems. These values have been calculated based on the dynamic radiative forcing approach, described in Section 4.1.6.1 of this report.[13] An explanation of the factors contributing to the radiative forcing is shown in Table 6.1.

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[12] Non-biogenic CO_2 GHGs only. Calculated as follows: (CHP_Typ - A - B - C - MR1)/(A+B+C+MR1).
[13] In Figure 6.2 and Figure 6.3, radiative forcing due to the GHG emissions is plotted in units of Wm^{-2} instead of units of CO₂E because, when using dynamic radiative forcing calculations, the relationship between annual and cumulative results is much easier to illustrate visually using units of Wm^{-2}. For other residuals addressed later in this report, only the differential cumulative results are shown.
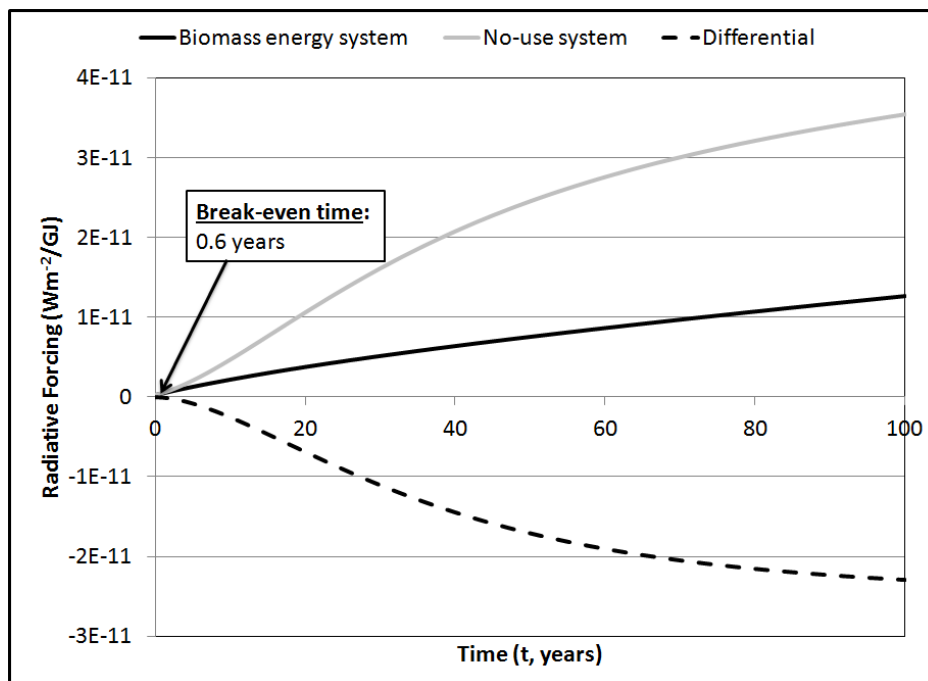
Figure 6.2 Annual GHG Impact for the Biomass Energy and Non-Use Systems:
Woody Mill Residuals - Typical Scenario

Table 6.1 Explanation of Annual Emissions, Woody Mill Residuals, Dynamic Carbon Footprinting

Time (years)	Biomass Energy System	Non-Use System	Differential (i.e., biomass energy system minus non-use system)
t = 0	The woody residuals are burned, releasing GHGs, which result in radiative forcing at the time of combustion of $2.49E-13$ Wm^{-2}.	The fossil fuels are burned, releasing GHGs, which result in radiative forcing at the time of combustion of $2.25E-13$ Wm^{-2}. Biomass residuals are placed in landfills. There are no releases from the landfills at time 0.	The differential radiative forcing is positive $(0.23E-13$ $Wm^{-2})$ because at time 0 there is more forcing from the emissions released by the biomass energy system than from the non-use system.
$0 < t < \infty$	There are no additional emissions from the biomass energy system. The radiative forcing caused each year by GHGs released in year 0 slowly declines as these GHGs degrade (e.g., CH_4) or are removed from the atmosphere (e.g., CO_2).	Although there are no additional emissions from combustion, residuals start degrading in landfills releasing GHGs. In each year, there is radiative forcing from landfill GHGs released in the current year plus forcing due to GHGs released in previous years that are still in the atmosphere. During the period that landfill emissions are high, annual radiative forcing increases because the forcing from new emissions increases faster than previously emitted GHGs are removed from the atmosphere. Over time, however, the GHG releases from landfills decline and approach zero and the GHGs in the atmosphere degrade (e.g., CH_4) or are removed from the atmosphere (e.g., CO_2). As a result, the annual radiative forcing approaches zero.	The differential radiative forcing goes through a minimum and then increases, approaching zero, because the emissions from both systems eventually degrade or are removed from the atmosphere.

While Figure 6.2 shows the annual radiative forcing, Figure 6.3 shows the same data but plotted as cumulative radiative forcing, in units of Wm^{-2}, associated with emissions of GHGs in the biomass energy and non-use systems for woody mill residuals as a function of time. An explanation of the sources of this radiative forcing is provided in Table 6.2. Figure 6.3 shows that the differential radiative forcing is initially positive because the forcing due to the emissions from the biomass energy system is higher than that for the non-use system. The differential cumulative greenhouse gas impact quickly becomes negative, however, as landfill emissions increase in the non-use scenario. The figure shows that, under the typical scenario assumptions (e.g., alternative fate is 100% landfill), it takes 0.6 years before the cumulative radiative forcing due to GHG releases in the biomass energy system is less than the radiative forcing due to releases in the non-use system.

Figure 6.3 Cumulative GHG Impact for the Biomass Energy and Non-use Systems:
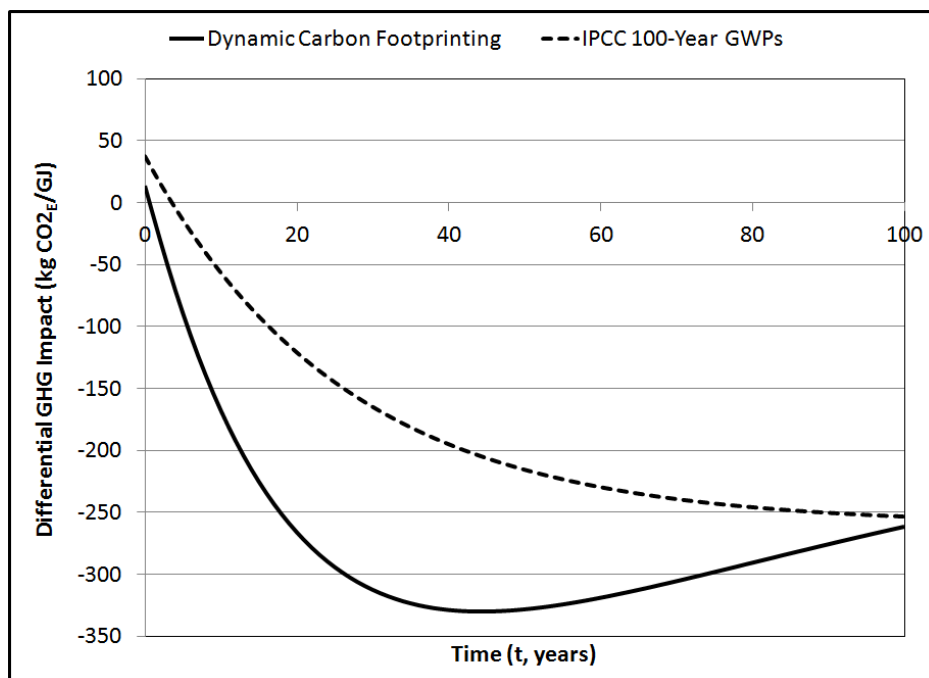Woody Mill Residuals - Typical Scenario

Table 6.2 Explanation of Cumulative Emissions, Woody Mill Residuals

Time (years)	Biomass Energy System	Non-Use System	Differential (i.e., biomass energy system minus non-use system)
t = 0	The woody residuals are burned, releasing GHGs, which result in radiative forcing at the time of combustion of $2.49E\text{-}13$ Wm^{-2}.	The fossil fuels are burned, releasing GHGs, which result in radiative forcing at the time of combustion of $2.25E\text{-}13$ Wm^{-2}. Biomass residuals are placed in landfills. There are no releases from the landfills at time 0.	The differential radiative forcing is positive ($0.23E\text{-}13$ Wm^{-2}) because at time 0, there is more forcing from the emissions released by the biomass energy system than from the non-use system.
0 < t < 0.6	There are no new emissions from the biomass energy system. The initially released GHGs remain in the atmosphere for a period of time, so each year, the cumulative radiative forcing increases.	Biomass residuals placed in landfills starts to degrade, releasing GHGs. The cumulative GHG emissions, and their cumulative radiative forcing, increase rapidly.	The difference in cumulative radiative forcing decreases as the forcing associated with the non-use system increases more rapidly that that associated with the biomass energy system.
t = 0.6	Cumulative radiative forcing reaches $3.9E\text{-}13$ Wm^{-2}.	Cumulative radiative forcing reaches $3.9E\text{-}13$ Wm^{-2}.	The cumulative differential radiative forcing is 0 (break-even time).
3.6 < t < ∞	There are no new emissions from the biomass energy system but cumulative forcing continues to increase until all GHGs are removed from the atmosphere.	The emissions from the landfill continue for a considerable period. Cumulative radiative forcing continues to increase until all GHGs released from fossil fuel combustion and from disposal operations are removed from the atmosphere.	At 100 years, the difference in cumulative radiative forcing is $-2.29E\text{-}11$ Wm^{-2}. The difference changes only slowly after this point.

Figure 6.4 compares the timing of differential cumulative GHGI results obtained using the dynamic carbon footprinting approach with those obtained using IPCC 100-year GWPs in units of kg CO_2E. The first observation that can be made from that chart is that the differential cumulative GHGI results decline faster when using the dynamic carbon footprinting approach than with IPCC GWPs. In other words, more short-term benefits from using biomass residuals for energy production are observed when applying dynamic carbon footprinting. The break-even time is 0.6 years using dynamic carbon footprinting and 3.6 years when using IPCC global warming potentials. The difference is due to the methane released from the landfills under the non-use scenario. Methane is a potent greenhouse gas but it has a short lifetime in the atmosphere so its greenhouse gas impact is concentrated in the years immediately following its release, as opposed to carbon dioxide, which is much more persistent.

Another difference is that, while the cumulative greenhouse gas impact is steadily going down to reach a plateau using IPCC GWPs, it goes through a minimum using the dynamic carbon footprinting approach. Again, this is because of the greater impact of methane emissions from the non-use scenario in the early years of the simulation. As the methane decomposes to CO_2, the results for dynamic modeling and 100-year GWPs become similar.

Figure 6.4   Emissions Timing: Comparing Results Based on Dynamic Carbon Footprinting and
IPCC 100-Year GWPs

6.1.1.4   ***Consumption of Fossil Fuels***

Figure 6.5 shows the relative consumption of fossil fuels ("Relative FF CON," biomass energy
system compared to non-use system). It can be seen from the figure that fossil fuel use in the biomass
energy system is 100% lower; virtually no fossil fuels are used in the biomass energy system. It can
also be seen from the figure that the main contributor to the difference between the systems is the heat
from natural gas in the non-use system.

Figure 6.5 Relative Consumption of Fossil Fuels for Woody Mill Residuals - Typical Scenario
[In the figure, the different components of the biomass energy system are depicted as follows: CHP system as described in Figure 5.3 (CHP_Typ). The components of the non-use system are depicted as follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residual in landfills (MR1).]

6.1.2   Typical Scenario: Perturbation and Sensitivity Analyses

6.1.2.1   *Perturbation Analyses*

As mentioned in Section 4.1.3, sensitivity ratios represent the percent change in an output variable caused by a 1% change in one given input variable. For simplicity and given that the GHGI results do not vary significantly over a 100-year period depending on the approach used, perturbation analyses were performed using IPCC 100-year GWPs. Figure 6.6 shows the sensitivity ratios for the four indicators analyzed in this study, for woody mill residuals. The following input variables were tested in sensitivity analyses: transportation distance of the residuals (Distance), their water content (WC_R), their heating value (HHV), and the fraction of their carbon content that is non-degradable carbon (F_{CCND}).

The results depicted in Figure 6.6 should be interpreted as follows. A sensitivity ratio of +1.0 means that value of the output variable increases by 1% when the input variable value is increased by 1%. The greater the absolute value of the sensitivity ratio, the more intrinsically sensitive a parameter was.

It can be seen from Figure 6.6 that transportation distance of residuals to the boiler had very little effect on the "Differential GHGI" indicator results when compared to the other studied parameters. The fraction of non-degradable carbon (F_{CCND}) had the most significant effect on the results, with sensitivity ratios of 1.4. The positive ratio means that when increasing the value of the parameter, the indicator result is also increased, indicating a declining performance of the biomass energy system compared to the non-use system. Increasing the water content of the residuals, and thus reducing the boiler efficiency, produced a negative sensitivity ratio, i.e., a positive effect on the results. This is because on a per gigajoule basis, more residuals are required to produce the energy and thus more

landfilling, and associated methane emissions from landfills, are avoided. The opposite can be seen when increasing the higher heating value.

The time for biomass energy system to have lower cumulative emissions than the non-use system ("break-even time" in Figure 6.6) was significantly affected, relatively speaking, by the various parameters analyzed, except for the transportation distance of residuals.

Finally, overall, the relative GHGI and relative fossil fuel consumption indicator results were not significantly affected by the parameters analyzed.

Figure 6.6 Sensitivity Ratios for Woody Mill Residuals

6.1.2.2 *Sensitivity Analyses*

Above, perturbation analyses were applied to determine which parameters were intrinsically the most sensitive to the results without considering the actual ranges of possible values for these parameters. In Table 4.1, the results of sensitivity analyses considering the actual possible ranges of variation for each parameter are presented. It is shown that the range of possible heating values for woody mill residuals had the most effect on the results. Also, even with the highest heating value for residuals, the GHG benefits of the biomass energy system compared to the non-use system are still considerable.

Table 6.3 Sensitivity Analyses on Indicator Results for the Typical Scenario, Woody Mill Residuals

Para-meter	Differential GHGI* (kg CO₂E/GJ)			Relative Non-BioCO₂ GHGI* (%)			Break-Even Time* (years)			Relative FF CON (%)		
	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max
WC$_R$		-229	-268		-99.1	-99.2		0.9	2.5		-100	-100
HHV		-219	-334		-99.0	-99.2		0.3	3.9		-100	-100
F$_{CCND}$	-254†	-254	-318	-99.1 ‡	-99.1	-99.3	3.6 §	1.6	4.7	-100	-100	-100
Transp. of residuals		-252	-254		-99.1	-99.1		2.1	3.6		-100	-100
k		-254	-254		-99.1	-99.1		2.5	7.0		-98.2	-100

*Computed using IPCC 100-Year GWPs. †-261 kg CO₂E/GJ using dynamic modeling of cumulative radiative forcing. ‡ -99.1% using dynamic modeling of cumulative radiative forcing. §0.6 years using dynamic modeling of cumulative radiative forcing.

6.1.3   System Configuration Scenarios

In Section 5.0, various system configuration scenarios were presented. For instance, it was noted that the alternative fate of woody mill residuals was difficult to determine. While the typical scenario assumed 100% landfilling, it might well be incineration. System configuration scenarios were used to analyze those system configuration assumptions that are uncertain.

All possible scenario combinations presented in Section 5.1 were analyzed (132 combinations). The calculations were performed using IPCC 100-year GWPs. Results are presented in Table 6.4 for cases where parameters would be at their base case value. GHG releases and fossil fuel consumption are significantly lower for all cases. Maximum differences were obtained in cases in which

- there is no size reduction;
- combined heat and power with maximum power production is produced;
- coal is being displaced (for both heat and power production);
- there is no transportation; and
- alternative fate is landfilling.

Minimum differences were obtained in cases in which

- there is size reduction;
- only heat is produced;
- natural gas is being displaced (for both heat and power production);
- there is transportation; and
- alternative fate is incineration.

Results in Table 6.4 also show that the time for the biomass energy system to have lower cumulative emissions than the non-use system varies between 0 and 4.5 years, the lowest being observed when incineration is the alternative fate.

Table 6.4 Indicator Results for Various System Configuration Scenarios, Woody Mill Residuals

Indicator	Unit	Typical	Min	Max
Differential GHGI*	kg CO_2E/GJ	-254†	-78.4	-458
Relative non-BioCO$_2$ GHGI*	%	-99.1‡	-94.9	-99.4
Break-even time*	years	3.6§	0	4.5
Relative FF CON	%	-100%	-98.5	-100

*Computed using IPCC 100-Year GWPs. † -261kgCO_2E/GJ using dynamic modeling of cumulative radiative forcing. ‡ -99.1% using dynamic modeling of cumulative radiative forcing. §0.6 years using dynamic modeling of cumulative radiative forcing.

6.2   WWTP Residuals

This section presents results for the WWTP residuals.

6.2.1   Typical Scenario: Base Case Results

The typical scenario was first analyzed with all parameters at their base case values.
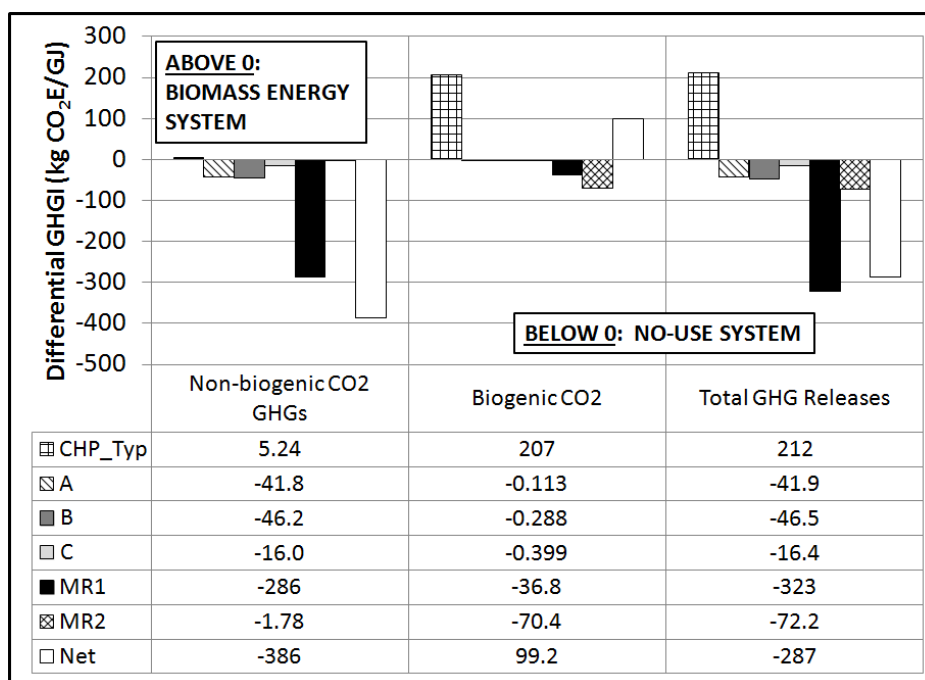
6.2.1.1   *Greenhouse Gases: Differential GHGs*

When using the dynamic carbon footprinting approach, the biomass energy system produces, after 100 years, a greenhouse gas impact that is **295 kg CO_2E lower**[14] per gigajoule of energy produced compared to the defined non-use system. This reduction is **287 kg CO_2E** when applying IPCC 100-year GWPs.

Figure 6.7 presents the 100-year differential GHGI for the biomass energy system compared to the non-use system as well as the contribution of each system component to the results using IPCC 100-year GWPs. In this figure, emissions from the non-use system are shown as a negative number because to obtain the Differential GHGs indicator overall result, the emissions of the non-use scenario were subtracted from those of the biomass energy system.

The figure shows that non-biogenic CO_2 GHGI is mostly lower because when burning residuals to produce energy, there are no methane emissions from landfills. The fact that there is less heat generated from fossil fuels also contributes to the lower impact, but to a lesser extent. Emissions of biogenic CO_2 are different in the two systems for two reasons. First, much of the biogenic carbon is released as methane in the non-use system (included within non-biogenic CO_2 GHGs) and mostly as CO_2 in the biomass energy system. Second, some of the carbon is stored in landfills in the non-use system.

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[14] Results in this report are always presented as differences (i.e., biomass energy system minus non-use system). The "Relative GHGI" indicator does not include biogenic CO_2. The "Differential GHGI" indicator includes emissions and removals of biogenic CO_2.

	Non-biogenic CO2 GHGs	Biogenic CO2	Total GHG Releases
⊞ CHP_Typ	5.24	207	212
◩ A	-41.8	-0.113	-41.9
▪ B	-46.2	-0.288	-46.5
☐ C	-16.0	-0.399	-16.4
■ MR1	-286	-36.8	-323
⊠ MR2	-1.78	-70.4	-72.2
☐ Net	-386	99.2	-287

Figure 6.7 Contribution Analysis for the Differential GHGI (at 100 Years)
for WWTP Residuals - Typical Scenario
[In the figure, the different components of the biomass energy system are depicted as follows: CHP
system as described in Figure 5.4 (CHP_Typ). The components of the non-use system are depicted as
follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residual in
landfills (MR1), incineration of residuals (MR2). Results reflect the use of 100-year GWPs.]
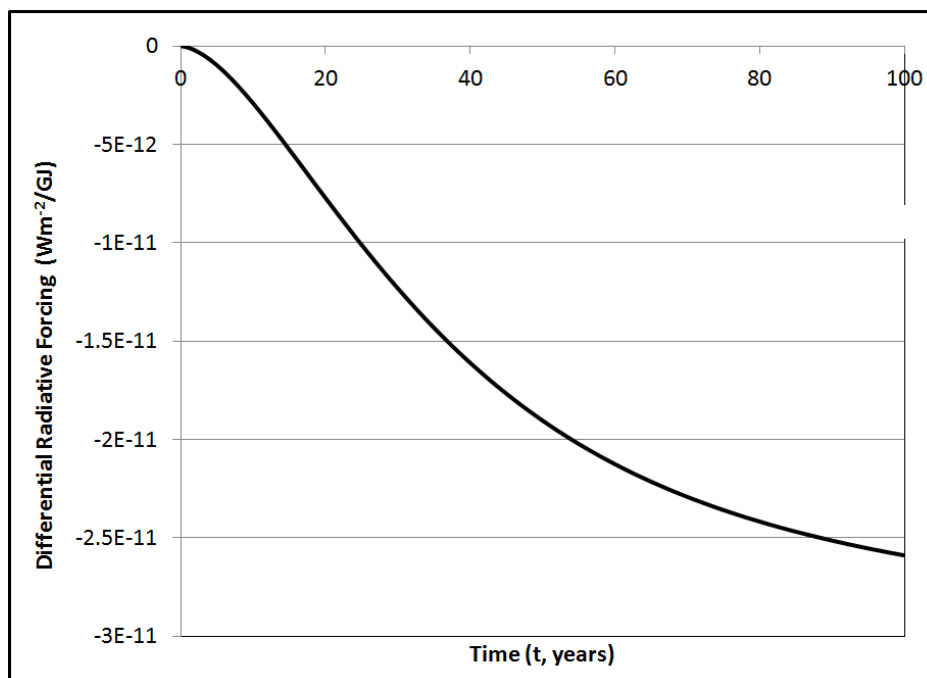
6.2.1.2 *Greenhouse Gases: Relative Non-BioCO₂ GHGs*

The result for the "Relative Non-BioCO$_2$ GHGs" indicator is -98.7%[15] (-99.1% using IPCC GWPs),
meaning that the biomass energy system generates almost no GHGs when ignoring biogenic CO$_2$ and
hence, produces a significant reduction when compared to the non-use system.

6.2.1.3 *Greenhouse Gases: Timing of Impacts*

When WWTP residuals are burned for energy, the related biogenic carbon is released to the
atmosphere immediately. In contrast, WWTP residuals placed into landfills degrade slowly, releasing
the related biogenic carbon (both CO$_2$ and CH$_4$) over time. Figure 6.8 presents the results of the
"Differential GHGI" indicator over time using USEPA's decay rates for materials placed in municipal
landfills, for the typical scenario. These results were developed using the dynamic carbon footprinting
approach described in Section 4.1.6.1 of this report and are expressed in units of radiative forcing
(Wm^{-2}). The net difference is initially negative (i.e., the impact from the biomass energy system is
lower than that from the no-use system from time equals zero, meaning that the break-even time is
zero) and then declines over time as the material degrades in landfills. When using IPCC 100-year
GWPS, the difference in impact is initially positive and the break-even time is observed at 1.8 years.

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[15] Non-biogenic CO$_2$ GHGs only. Calculated as follows: (CHP_Typ - A - B - C - MR1- MR2)/
(A+B+C+MR1+MR2).

Figure 6.8 Cumulative Differential GHGI Indicator Results as a Function of Time
for WWTP Residuals - Typical Scenario

6.2.1.4   *Consumption of Fossil Fuels*

Figure 6.9 shows the results for the relative consumption of fossil fuels indicator ("Relative FF
CON," biomass energy system compared to non-use system).

It can be seen from Figure 6.9 that the biomass energy system used 99.3% less fossil fuel when
compared to the non-use system defined in this study. This is due to the fact that virtually no fossil
fuels are used in the biomass energy system. It can also be seen from the figure that the main
contributor to the lower emissions is avoided heat from natural gas.

Figure 6.9 Relative FF CON Indicator Results for WWTP Residuals - Typical Scenario
[In the figure, the different components of the biomass energy system are depicted as follows: CHP
system as described in Figure 5.4 (CHP_Typ). The components of the non-use system are depicted as
follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residual in
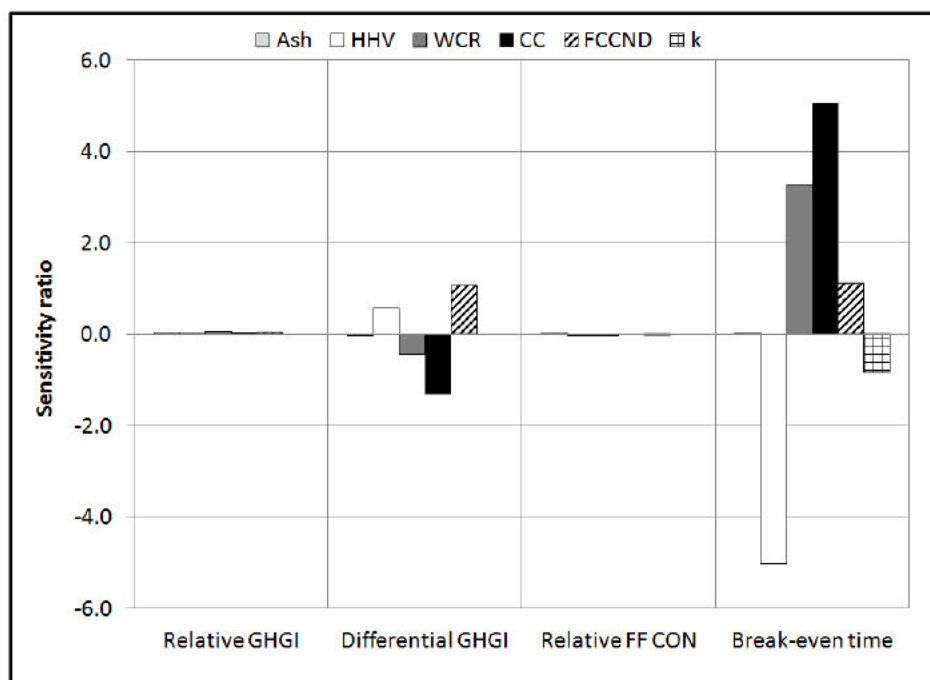landfills (MR1), incineration of residuals (MR2).]

6.2.2   Typical Scenario: Perturbation and Sensitivity Analyses

6.2.2.1   Perturbation Analyses

Various parameters were analyzed in perturbation analyses. For each of these parameters, a sensitivity
ratio was calculated (see Section 4.1.3). For simplicity and given that the GHGI results do not vary
significantly over a 100-year period depending on the approach used, perturbation analyses were
performed using IPCC 100-year GWPs.

Sensitivity ratios for the parameters tested in this study are presented in Figure 6.10. It can be seen
from that figure that the carbon content of the residuals has the most significant effect on the GHGI
results, with a sensitivity ratio of -1.3. The negative ratio means that when increasing the value of the
parameter, the score is decreased, indicating an improving performance of the biomass energy system
compared to the non-use system. The fraction of non-degradable carbon (F_{CCND}) also has significant
effect on the Differential GHGs results, with sensitivity ratio of 1.1. The positive ratio means that
when increasing the value of the parameter, the score is also increased, indicating a declining
performance of the biomass energy system compared to the non-use system. Increasing the water
content of the residuals, and thus reducing the boiler efficiency, produced a negative sensitivity ratio,
i.e., a positive effect on the results. This is because on a per gigajoule basis, more residuals are
required to produce the energy; thus, more landfilling and associated methane emissions from
landfills are avoided. The opposite can be seen when increasing the higher heating value. Overall,
Relative GHGs and fossil fuel consumption results were not significantly affected by the parameters
analyzed. Break-even time was shown, relatively speaking, to be highly sensitive to all parameters
tested, with the exception of the ash content.

Figure 6.10 Sensitivity Ratios for WWTP Residuals

6.2.2.2   Sensitivity Analyses

Above, perturbation analyses were applied to determine which parameters were intrinsically the most sensitive to the results without considering the actual ranges of possible values for these parameters. In Table 6.8, the results of sensitivity analyses considering the actual possible ranges of variation for each parameter are presented. It is shown that the range of possible heating values and carbon content for WWTP residuals had the most effect on the results. Also, even in the worst conditions, the GHG benefits of the biomass energy system compared to the non-use system are still considerable.

Table 6.5 Sensitivity Analyses on Indicator Results for the Typical Scenario, WWTP Residuals

Para-meter	Differential GHGI* (kg CO$_2$E/GJ)			Relative Non-BioCO$_2$ GHGI* (%)			Break-Even Time* (years)			Relative FF CON (%)		
	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max
WC$_R$		-271	-311		-98.6	-98.7		1.0	3.0		-99.2	-99.4
HHV		-242	-378		-98.5	-98.8		0	5.6		-99.0	-99.5
Ash	-287†	-287	-288	-99.1 ‡	-98.5	-98.8	1.8§	1.9	3.0	-99.3	-98.8	-99.8
CC		-182	-309		-97.7	98.8		0	3.0		-99.3	-99.3
F$_{CCND}$		-217	-287		-98.7	-98.7		1.6	2.4		-99.3	-99.3
k		-287	-287		-98.7	-98.7		1.3	3.5		-99.3	-99.3

*Computed using 100-year GWPs.†-295 kg CO$_2$E/GJ using dynamic modeling of cumulative radiative forcing. ‡-98.7% using dynamic modeling of cumulative radiative forcing. §0.0 years using dynamic modeling of cumulative radiative forcing.

6.2.3   System Configuration Scenarios

In Section 5.0, various system configuration scenarios were presented. All relevant scenario combinations were analyzed (40 combinations). Results are presented in Table 6.6 for cases where parameters would be at their base case, worst, or best values. Results obtained for the typical scenarios are also reproduced in this table for comparison purposes. GHG releases and fossil fuel consumption are significantly lower for all cases. Maximum differences were obtained in cases in which

- combined heat and power with maximum power production is produced;
- coal is being displaced (for both heat and power production); and
- alternative fate is landfilling.

Minimum differences were obtained in cases in which

- only heat is produced;
- natural gas is being displaced (for both heat and power production); and
- alternative fate is incineration.

Table 6.6 Indicator Results for Various System Configuration Scenarios - WWTP Residuals

Indicator	Unit	Typical	Min	Max
Differential GHGI*	kg CO_2E/GJ	-287**	-79.5	-589
Relative Non-BioCO$_2$ GHGs *	%	-99.1	-93.9	-99.3
Break-even time*	years	1.8§	0	6.4
Relative FF CON	%	-99.3	-99.1	-99.7

*Computed using 100-year GWPs.†-295 kg CO_2E/GJ using dynamic modeling of cumulative radiative forcing. ‡-98.7% using dynamic modeling of cumulative radiative forcing. §0.0 years using dynamic modeling of cumulative radiative forcing

6.3   Paper Recycling Residuals

6.3.1   Typical Scenario: Base Case Results

The typical scenario was first analyzed with all parameters at their base case values.

6.3.1.1   Greenhouse Gases: Differential GHGs

When using the dynamic carbon footprinting approach, the biomass energy system produces, after 100 years, a greenhouse gas impact that is **112 kg CO_2E lower**[16] per gigajoule of energy produced compared to the defined non-use system. This reduction is **109 kg CO_2E** when applying IPCC 100-year GWPs.

Figure 6.11 shows that the non-biogenic CO_2 GHGI is mostly lower because when burning residuals to produce energy, there are no methane emissions from landfills. Alone, the avoided methane emissions from landfills lower the impact by 154 kg CO_2E/GJ. The fact that there is less heat from

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[16] Results in this report are always presented as differences (i.e., biomass energy system minus non-use system). The "Relative GHGI" indicator does not include biogenic CO_2. The "Differential GHGI" indicator includes emissions and removals of biogenic CO_2.

fossil fuels also contributes to the lower impact, but to a lesser extent. Emissions of biogenic CO_2 are different in the two systems for two reasons. First, much of the biogenic carbon is released as methane in the non-use system (included within non-biogenic CO_2 GHGs) and mostly as CO_2 in the biomass energy system. Second, some of the carbon is stored in landfills in the non-use system.

	Non-biogenic CO2 GHGs	Biogenic CO2	Total GHG Releases
CHP_Typ	55.29	63	119
A	-41.8	-0.113	-41.9
B	-46.2	-0.288	-46.5
C	-16.0	-0.399	-16.4
MR1	-101	-12.7	-114
MR2	-4.24	-4.0	-8.3
Net	-154	45.7	-109

Figure 6.11 Contribution Analysis for the Differential GHGI (at 100 Years)
for Paper Recycling Residuals - Typical Scenario
[In the figure, the different components of the biomass energy system are depicted as follows: CHP system as described in Figure 5.5 (CHP_Typ). The components of the non-use system are depicted as follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residual in landfills (MR1), incineration of residuals (MR2). Results reflect the use of 100-year GWPs.]

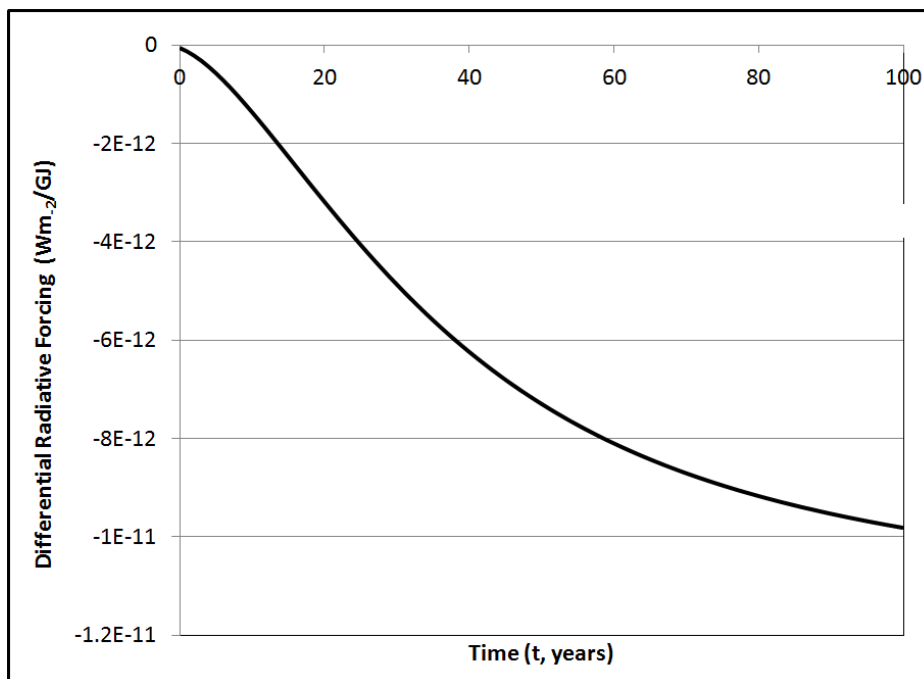### 6.3.1.2   *Greenhouse Gases: Relative Non-BioCO₂ GHGs*

The result for the "Relative Non-BioCO₂ GHGI" indicator is -86.4%[17] (-75.2% when using IPCC GWPs), meaning that the biomass product system generates almost no GHGs when ignoring biogenic CO_2. When compared to other types of residuals presented above (woody mill residuals and WWTP residuals), the use of paper recycling residuals presents significantly lower overall benefits. This is because paper recycling residuals are composed of an important fraction of plastic which, when combusted, releases fossil fuel GHGs.

6.3.1.3   *Greenhouse Gases: Emissions Timing*

When paper recycling residuals are burned for energy, the biogenic carbon (both CO_2 and CH_4) is immediately released to the atmosphere. In contrast, residuals placed into landfills degrade slowly, releasing the carbon over time. Figure 6.12 analyzes the "Differential GHGI" indicator results over

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[17] Non-biogenic CO_2 GHGs only. Calculated as follows: (CHP_Typ - A - B - C - MR1 - MR2)/ (A+B+C+MR1+MR2).

time using USEPA's decay rate for materials placed in municipal landfills for the typical scenario. It shows that the differential impact is initially slightly negative (i.e., the impact from the biomass-based system is lower than that from the fossil fuel-based system, meaning that the break-even time is zero) and declines over time as the material degrades in landfills. When using the IPCC GWPs, the break-even time is also zero years.

Figure 6.12 Cumulative Differential GHGI Indicator Results as a Function of Time for Paper Recycling Residuals - Typical Scenario

6.3.1.4 **Consumption of Fossil Fuels**

Figure 6.13 shows the relative consumption of fossil fuels ("Relative FF CON," biomass energy system compared to non-use system) for paper recycling residuals.

It can be seen from that figure that the biomass energy system uses 99.9% less fossil fuel than the non-use system. This is due to the fact that virtually no fossil fuels are used in the biomass energy system. It can also be seen from the figure that the main contributor to the lower emissions is avoided heat from natural gas. Note that the plastic fraction of paper recycling residuals was not considered to be fossil fuel.

Figure 6.13 Relative Consumption of Fossil Fuels for Paper Recycling Residuals - Typical Scenario [In the figure, the different components of the biomass energy system are depicted as follows: CHP system as described in Figure 5.5 (CHP_Typ). The components of the non-use system are depicted as follows: heat from coal (A), heat from natural gas (B), US average power grid (C), residual in landfills (MR1), incineration of residuals (MR2).]
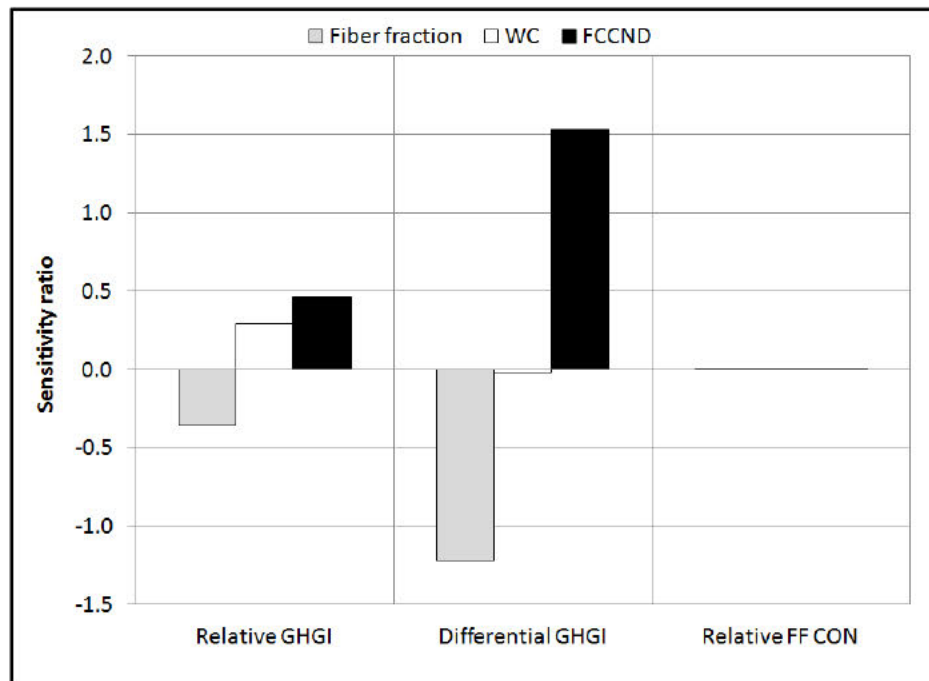
6.3.2   Typical Scenario: Perturbation and Sensitivity Analyses

6.3.2.1   *Perturbation Analyses*

Various parameters were analyzed in perturbation analyses. For each of these parameters, a sensitivity ratio was calculated (see Section 4.1.3). Sensitivity ratios for the parameters tested in this study are presented in Figure 6.14. Sensitivity ratios are not shown for break-even times as they were initially zero. It can be seen from Figure 6.14 that the fraction of non-degradable carbon (F_{CCND}) and the fiber fraction of paper recycling residuals have the most significant effect on the results, with sensitivity ratios up to 1.5. The positive ratio obtained for F_{CCND} means that when increasing the value of the parameter, the score is also increased, indicating a declining performance of the biomass energy system compared to that of the non-use system. Increasing the fiber fraction resulted in a negative sensitivity ratio. This means the biomass energy system generated lower emissions or consumed less fossil fuel than the non-use system. The water content of the residuals had little effect on the results compared to the other parameters. Finally, overall, fossil fuel consumption scores were not significantly affected by the parameters analyzed.

Figure 6.14 Sensitivity Ratios for Paper Recycling Residuals: Relative Non-BioCO2 GHGs, Differential GHGs, and Relative FF CON

6.3.2.2 *Sensitivity Analyses*

Above, perturbation analyses were applied to determine which parameters were intrinsically the most sensitive to the results without considering the actual ranges of possible values for these parameters. In Table 6.7, the results of sensitivity analyses considering the actual possible ranges of variation for each parameter are presented. It is shown that the range of possible heating values for paper recycling residuals had the most effect on the results. Also, even with the highest heating value for residuals, the GHG benefits of the biomass energy system compared to the non-use system are still considerable.

Table 6.7 Sensitivity Analyses on Indicator Results for the Typical Scenario, Paper Recycling Residuals

Para-meter	Differential GHGI* (kg CO$_2$E/GJ)			Relative Non-BioCO$_2$ GHGI* (%)			Break-Even Time* (years)			Relative FF CON (%)		
	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max	Typ	Min	Max
Fiber fraction	-109‡	-57.8	-191	-75.2 ‡	-49.6	-93.2	0§	0	2.3	-99.9	-99.9	-99.9
WC$_R$		-108	-109		-71.5	-75.1		0	3.4		-99.9	-99.9
FCCND		-109	-166		-75.2	-78.7		0	0		-99.9	-99.9
k		-109	-109		-75.2	-75.2		0	-0.7		-99.9	-99.9

*Computed using 100-year GWPs.†-112 kg CO$_2$E/GJ using dynamic modeling of cumulative radiative forcing. ‡-86.4% using dynamic modeling of cumulative radiative forcing.§0 years using dynamic modeling of cumulative radiative forcing.

6.3.3   System Configuration Scenarios

In Section 5.0, various system configuration scenarios were presented. All relevant scenario combinations were analyzed (40 combinations). Results are presented in Table 6.8 for cases where parameters would be at their base case, worst, or best values. Results obtained for the typical scenarios are also reproduced in that table for comparison purposes. The biomass energy system resulted in lower GHG releases and fossil fuel consumption in almost all cases. Maximum differences were obtained in cases in which

- the fiber fraction of paper recycling residuals is higher;
- combined heat and power with maximum power production is produced;
- coal is being displaced (for both heat and power production); and
- alternative fate is landfilling.

Minimum differences were obtained in cases in which

- the plastic fraction of paper recycling residuals is higher;
- only heat is produced;
- natural gas is being displaced (for both heat and power production); and
- alternative fate is incineration.

In one specific case, slightly higher GHG releases were calculated for the biomass energy system compared to the non-use system. This effect was relatively small compared to the lower emissions observed all other cases. The higher emissions occurred under the following conditions:

- high fraction of plastic in paper recycling residuals (70%);
- heat production only;
- high water content (70%) of residuals and low boiler efficiency (54%);
- Natural gas being displaced; and
- Incineration being the alternative fate.

Table 6.8 Indicator Results for Various System Configuration Scenarios - Paper Recycling Residuals

Indicator	Unit	Typical	Min	Max
Differential GHGs*	kg CO_2E/GJ	-109†	-82.9	-316
Relative GHGs *	%	-75.2‡	-62.5%	-86.3%
Break-even time*	years	0§	0	7.6
Relative FF CON	%	-99.9	-99.9	-100

*Computed using 100-year GWPs.†- 112 kg CO_2E/GJ using dynamic modeling of cumulative radiative forcing.
‡-86.4% using dynamic modeling of cumulative radiative forcing. §0 years using dynamic modeling of cumulative radiative forcing.

6.4   Black Liquor

In a previous study by NCASI (Gaudreault et al. 2012; NCASI 2011b), the benefits of recovering black liquor for production of energy and pulping chemicals that would otherwise need to be produced from other resources were analyzed. In that study, it was determined that developing a detailed model of the alternative fate of black liquor would have required too much speculation because black liquor is not disposed. Its use in the kraft recovery cycle is integral to pulp production. Nonetheless, it was reasonable to assume that alternative management would involve returning the biogenic carbon in the liquor to the atmosphere, perhaps via incineration (in which case the carbon is emitted immediately), or aerobic wastewater treatment(in which case the carbon would be emitted

over a period of hours to months depending on the type of treatment system in use). In either case, the carbon is returned to the atmosphere far too quickly to make carbon storage a significant factor in the calculations. To be conservative, it was also assumed that all of the carbon in the black liquor would be emitted as CO_2. If, in the alternative management scenario, some of the carbon was emitted as methane, the benefits of using black liquor in the kraft recovery cycle would be larger than estimated in the study.

The detailed results obtained for black liquor can be found in NCASI (2011b) and Gaudreault et al. (2012). These are summarized in Table 6.9. At the time of this earlier study, no dynamic carbon footprint approach was applied and the results were not limited to 100 years. The break-even time would remain zero using dynamic carbon footprint but limiting the analysis to 100 years would slightly reduce the GHG benefits.

Table 6.9 Summary of Indicator Results for Black Liquor

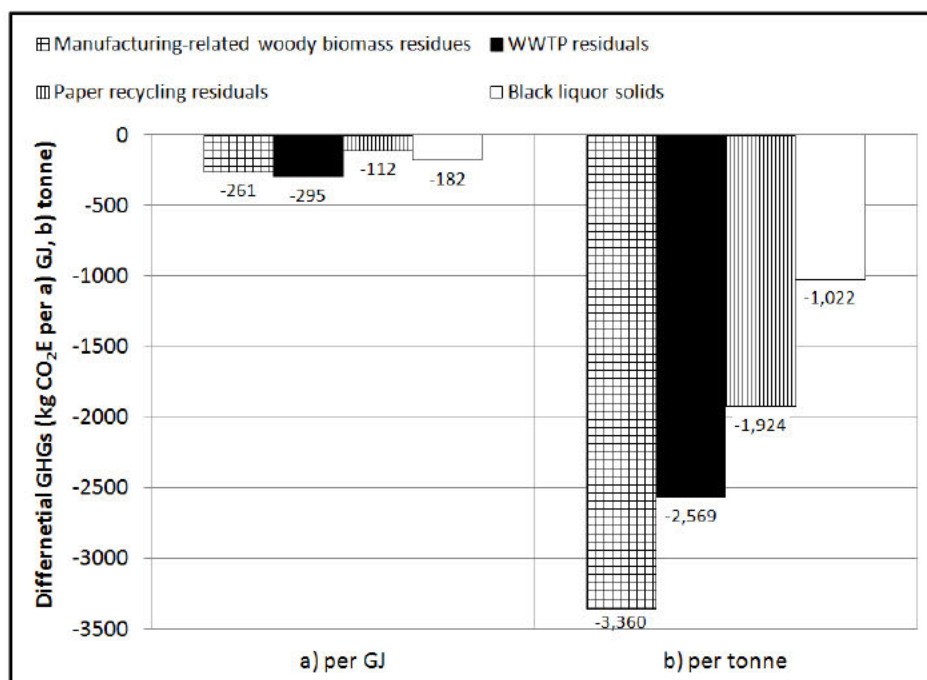| Indicator	Unit	Typical	Min	Max
Differential GHGI*	kg CO_2E/GJ	-182	-97.9	-192
Relative Non-BioCO$_2$ GHGI*	%	-90.5	-69.0	-92.4
Break-even time*,†	years	0	Not available	
Relative FF CON	%	-89.8	-71.1	-90.7

* Based on 100-year GWPs. † Break-even time was not analyzed in NCASI (2011b) and Gaudreault et al. (2012). However, assuming that the most likely alternative fate for black liquor is incineration, consistent with the conservative assumption made regarding carbon emission from this alternative fate, the break-even time would be zero years.

6.5   Comparison of the Residuals

Figure 6.15 compares the GHG benefits for the different types of biomass residuals on a) a functional unit basis (i.e., 1 GJ of energy), and b) a tonne of residual basis. "Differential GHGs" indicator results are depicted for the biomass energy system compared to the non-use system.

The figure shows that producing 1 GJ of energy using WWTP residuals produces greater benefits than does using woody mill residuals. This may seem counterintuitive, as WWTP residuals are a fuel of lesser quality than woody biomass residuals. This result was obtained because to produce 1 GJ of energy, more WWTP residuals are needed than when using woody biomass residuals, which also means diverting more WWTP residuals from landfill and hence avoiding more methane emissions. Paper recycling residuals generated relatively lower benefits than woody biomass residuals and WWTP residuals. This was due to the plastic fraction of the residuals, which produce fossil fuel GHGs when burned.

On a per tonne of residual basis, fuels with higher HHV and lower water content led to greater benefits. The plastic fraction of paper recycling residuals was also an important factor explaining the lower benefits observed for this material.

Figure 6.15 Comparison of the Differential Releases for the Different Residual Types
a) per Gigajoule, b) per Tonne

It is also possible to use the numbers presented in Table 6.13 to calculate typical scenario weighted average indicator results for all residuals included in this study. The weighted average results are presented in Table 6.10.

Table 6.10 Weighted Average Indicator Results, Typical Scenarios, Life Cycle Results

Indicator	Unit	Weighted-Average Result (all manufacturing residuals)	
		Dynamic Carbon Footprint	IPCC GWPs
Differential GHGI	kg CO_2E/GJ	-208	-206
Relative non-bioCO_2 GHGI	%	-93.3	-93.3
Break-even time	years	0	1.2
Relative FF CON	%	-93.1	-93.1

6.6   Additional Sensitivity Analysis on Air Emission Control Equipment

As mentioned in Section 5.1.2.1, it was assumed in this study that the difference in energy requirements for air emission control was negligible for boilers combusting biomass residuals, coal, and/or natural gas. There is very little information available regarding air emission control device energy requirements and where there is, it is rarely in a format that is usable for this study. Some of the available information is summarized in Table 6.11. Table 6.12 presents common air emission control equipment used for various boiler types within the forest products industry.

Based on the information in Table 6.11 and Table 6.12, two sensitivity analyses were performed to test the significance of the differences in control equipment and are summarized in Table 6.13. The results of the sensitivity analyses, presented in Figure 6.16, indicate that neglecting the differences in

energy requirements for air emission control has likely led to a slight overestimation (of less than 3%) of the benefits related to the biomass energy system, especially in the context of fossil fuel consumption benefits.

Table 6.11 Power Consumption for Various Air Emission Control Devices

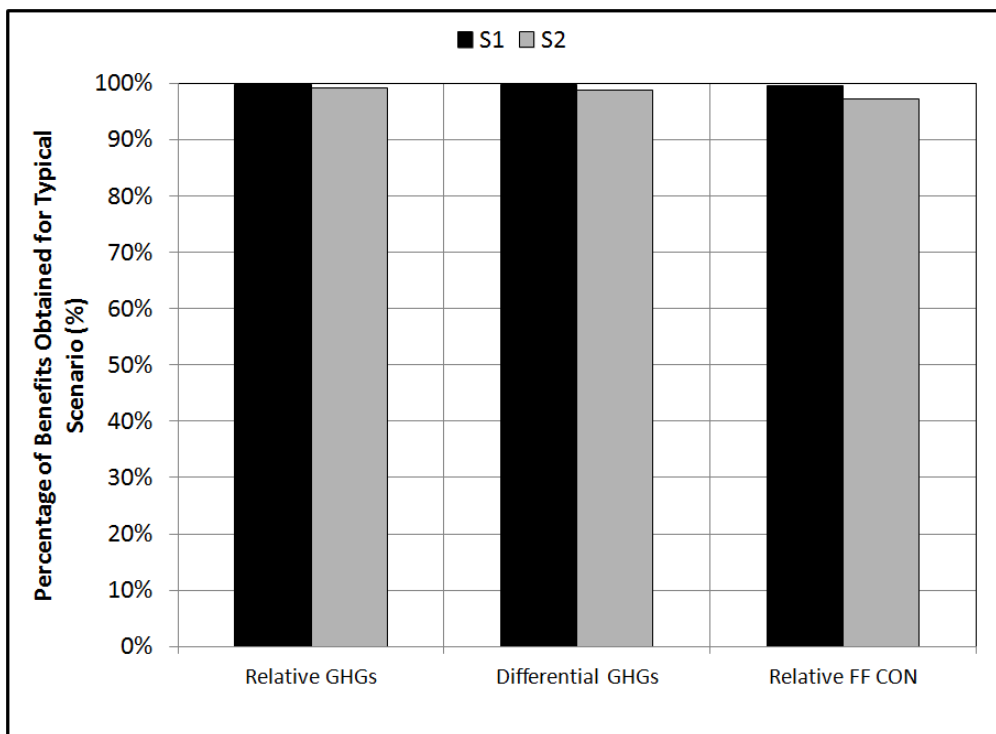| Air Emission Control Equipment	Power Consumption (% of energy output)	Applicability	Reference
Electrostatic precipitator	0.1 - 1.8%	Power utilities	European Commission (2006)
	0.2%*	Heat from coal	NCASI (1998)
	0.3%†	Heat from biomass	NCASI (1998)
	≈ 0.6%	Heat from coal‡	USEPA (2002)
Wet scrubber	≤ 3.0%	Power utilities	European Commission (2006)
Dry scrubber	0.3% - 1.0%	Power utilities	European Commission (2006)
	0.5% - 1.0%	Heat production	Kitto (1996)
Unspecified scrubber	1.0%*	Heat from coal	NCASI (1998)
	1.0%†	Heat from biomass	NCASI (1998)
Selective catalytic reduction (SCR)	0.5%	Power utilities	European Commission (2006)
Selective non-catalytic reduction (SNCR)	0.1 - 0.3%	Power utilities	European Commission (2006)

*Assuming 0.04 - 1.3 W/acfm, 0.5 acfm/(lb steam/hr) and 1.52E-03 GJ/lb steam. †Assuming 0.04 - 1.3 W/acfm, 0.92 acfm/(lb steam/hr) and 1.27E-03 GJ/lb steam.‡ Assuming 8640 hr/yr, 0.06$/kWh, 9780dscf/MMBtu, 3% O_2 at T=325°F.

Table 6.12 Common Combustion-Related Air Emission Control Equipment

Fuel Burned	Most common control equipment
Coal	ESP, low NO_x burner
Biomass	ESP, wet scrubber (newer boiler have SNCR for NO_x control)
Natural gas	Low NO_x burner, flue gas recirculation

Table 6.13 Sensitivity Analyses on Air Emission Control Equipment

#	Electricity Consumption for Air Emission Control (% of heat output)		
	Biomass	Natural Gas	Coal
S1	0.3%	0.0%	0.2%
S2	2.1%	0.0%	1.8%

Figure 6.16 Sensitivity Analyses on Air Emission Control Equipment -
Manufacturing-Related Woody Biomass Residuals - Typical Scenario

6.7   Life Cycle Results in Context

In this study, the life cycle GHG emissions and non-renewable energy consumption associated with the US forest products industry's use of biomass residuals (biomass energy system) have been compared to the GHG emissions and the non-renewable energy consumption that would occur if fossil fuels were used instead (non-use system). The results have been calculated in terms of the differences between these two systems, expressed in terms of value chain GHG emissions. In this section of the report, the calculated GHG benefits are put in the context of total emissions from the forest products industry value chain in 2010.

Table 6.13 presents data that allow calculation of the greenhouse gas benefits of using biomass residuals for energy generation. From this table, it can be seen that kraft black liquor and woody mill residuals represent 24.3% and 34.6%, respectively, of the total energy used by the industry, for an overall total of 58.9%.

Table 6.14 Various Contextual Data Regarding the US Forest Products Industry

Element		Value	Reference
Total energy consumption		2.58E9 GJ/yr	2010 data collected by AF&PA, NCASI, and AWC and scaled up to total US production*
Fraction of total energy from woody mill residuals (not including purchased power)		24.3%	
Fraction of total energy from black liquor generated in kraft pulping† (not including purchased power)		34.6%	
Fraction of biomass energy from various sources†	Spent liquor	66.07%	2010 data collected by AF&PA, NCASI, and AWC and scaled up to total US production*
	Woody mill residuals	29.15%	
	Forest harvest residuals	3.30%	
	WWTP residuals	0.70%	
	Paper recycling residuals	0.03%‡	
	Others	0.75%‡	
GHG benefits from black liquor recovery	Base Case	182 kg CO_2E/GJ in steam	Gaudreault et al. (2012)
	Min	98 kg CO_2E/GJ in steam	
	Max	192 kg CO_2E/GJ in steam	
Value chain emissions of the US forest products industry	Scope 1	64.6 million tonnes CO_2E/yr	Heath et al. (2010)
	Scopes 2 and 3	147 million tonnes CO_2E/yr	
	Net biogenic carbon flows	-109 million tonnes CO_2E/yr	
	Net value chain emissions	104 million tonnes CO_2E/yr	

*Together, AF&PA, NCASI, and AWC members comprise 96% of total US pulp production, 86% of total paper and paperboard production and 36% of wood products production. † Neglecting other insignificant sources of biomass energy. ‡ Estimated.

Based on these data, it is possible to estimate the increase in value chain emissions that would accompany the forest products industry's changing from woody mill residuals to fossil fuels. This calculation indicates that burning these residuals for energy in the forest products industry for one year avoids 110 million tonnes CO_2E[18] (ranging from 32.9 to 192 million tonnes CO_2E). A comparable analysis for black liquor was previously undertaken and published, with the conclusion that the use of black liquor in the kraft recovery system avoids the release of 182 kg CO_2/GJ (ranging from 98 to 192 kg CO_2E/GJ) (Gaudreault et al. 2012). Using the same data set as for woody mill residuals (2010 data), the current study indicates that the industry's use of black liquor in the kraft recovery system for one year avoids 109 million tonnes CO_2E (ranging from 59.0 to 115 million

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[18] All values calculated in this section of the report include the difference in releases of biogenic CO_2. In the case of the Heath et al. (2010), only the net flow of biogenic was shown, as only the net was calculated.

tonnes CO_2E) attributable to the use of black liquor in the kraft recovery system. Overall, therefore, the use of biomass-based manufacturing residuals in the forest products industry for one year avoids, for typical scenarios, the emissions of 218 million tonnes CO_2E (ranging from 91.5 to 307 million tonnes CO_2E). In an earlier study, it was determined that direct emissions of GHGs from fossil fuel combustion in the US forest products industry in 2004 were approximately 60 million tonnes CO_2E per year (Heath et al. 2010). The use of biomass-based manufacturing residuals for one year, therefore, avoids a quantity of GHG emissions more than three times the annual fossil-fuel related direct GHG emissions from the forest products industry.

7.0   RESULTS AND DISCUSSION: ADDITIONAL ANALYSES

This section presents the results of the gate-to-gate analysis of biogenic GHGs and the analysis of the emissions of GHGs in the context of ongoing practices.

7.1   Gate-to-Gate Analysis of Biogenic GHGs

All the results presented above were computed using a life cycle approach that considered the fossil fuels being displaced by biomass residuals. The typical scenarios for the two product systems (i.e., one system using biomass for energy and the other system managing it by some other means) have also been compared in terms of the emissions coming directly out of the units receiving the residuals (i.e., combustion units or landfills). In this analysis, the benefits of fossil fuel substitution were ignored. For the gate-to-gate analysis, paper recycling residuals were analyzed in terms of their fiber fraction only.

Gate-to-gate Differential GHGI results are summarized in Table 7.1. These show that, even in this highly constrained analysis, using the biomass residuals for energy generation resulted in significant GHG release reductions. A significant fraction of the emissions benefits were attributable to avoidance of landfill methane. A previous, similarly constrained analysis on black liquor assumed that the alternative management would almost certainly involve returning the biogenic carbon in the liquor to the atmosphere. In order to be conservative, in that study, it was assumed that the carbon would return to the atmosphere as CO_2 via incineration or treatment in aerobic wastewater treatment plants. This resulted in net zero GHG releases for energy production compared to an alternative fate. When not considering fossil fuel substitution, the weighted average improvement in GHG emissions associated with the use of all manufacturing residuals, including black liquor, was shown to be approximately 50 kg CO_2E/GJ.

Because the benefits of displacing fossil fuels are not included, the times required for cumulative emissions from the biomass energy system to fall below the cumulative emissions from the non-use system are longer than calculated earlier in this report. Depending on the residual, it required 0 to 7.7 years, with a weighted average of 2.4 years for typical scenarios (including black liquor), for the cumulative emissions from the biomass system to become lower than the cumulative emissions from the non-use system.

Table 7.1 Results of the Gate-to-Gate Analysis of Biogenic GHGs

Residual Type	Differential GHGs over 100 Years (kg CO₂E/GJ)		Break-Even Time (years)	
	Dynamic CF	**IPCC 100-Year GWPs**	**Dynamic CF**	**IPCC 100-Year GWPs**
Woody mill residuals	-154	-147	7.4	17.3
WWTP residuals	-190	-182	5.9	13.4
Fiber fraction of paper recycling residuals*	-132	-126	7.7	18.2
Black liquor	0	0	0	0
Weighted average of biomass manufacturing residuals	-51.1	-48.96	2.4	5.7

* In addition to biomass, paper recycling residuals contain plastics which are produced from fossil fuels. For the purpose of the biomass carbon fate analysis, only their fiber fraction was considered.

7.2   GHG Emissions from Ongoing Use of Residuals for Energy Production

Table 7.2 shows the times required for annual and cumulative emissions from a facility using residuals for energy to be equal to the emissions from a facility disposing of the residuals, both for the cradle-to-energy (including fossil fuel substitution) and gate-to-gate (excluding fossil fuel substitution) analyses. The results are presented for the dynamic carbon footprint approach only. The table also indicates when in the past the ongoing practice would have had to begin in order for the emissions from the two systems to be equal in 2014. The table includes text describing the practices in the industry at points in the past. It should be noted that there is considerable uncertainty in the estimates of break-even times, especially where fossil fuel substitution is ignored. This is because, in cases where fossil fuel substitution benefits are ignored, the curve describing the difference in cumulative emissions between the two scenarios is relatively flat as it approaches zero (because the initial difference between the scenarios is large). The break-even time is equal to the point at which the curve passes through zero, so the results are sensitive to small changes in assumptions, particularly assumptions about landfill decay and methane production. By contrast, where fossil fuel substitution is considered, the curve is steeper where it passes through zero because of the smaller initial difference between the two scenarios, thus reducing the uncertainty about break-even time.

Table 7.2 The Use of Residuals for Energy as an Ongoing Practice

Residual	Years For Emissions from Facility Using Residuals for Energy on an Ongoing Basis to Be Equal to Emissions from a Facility Disposing of These Residuals (Under Typical Scenario)		Year in the Past When Ongoing Practice Would Have Had to Be Initiated for Emissions from the Two Facilities to Be Equal in 2014 (Under Typical Scenario)		Past Industry Practice in Using the Residuals for Energy
	Annual Emissions	Cumulative Emissions	Annual Emissions	Cumulative Emissions	
Woody mill residuals — w/ benefits of the displaced fossil fuels (cradle-to-energy)	0.6	1.3	2013	2012	Based on AF&PA statistics, in 1971, woody mill residual represented 7% of the fuel (16% of the biomass) burned at pulp and paper mills. By 1980, this had increased to 11% of the fuel (21% of the biomass). Between 1987 and 1999, it varied between 15% and 18% of the fuel (25% to 29% of the biomass). Statistics for wood products mills are less robust, but woody fuels have been commonly used for lumber drying, and before that, steam engines, since these technologies were first introduced. The literature mentions the use of wood residuals in boilers used for wood drying at sawmills going back to at least 1920 and in steam engines in sawmills going back to the mid-1800s.
Woody mill residuals — w/o benefits of the displaced fossil fuels (gate-to-gate)	7.4	16.2	2007	1998	
WWTP residuals — w/ benefits of the displaced fossil fuels (cradle-to-energy)	0	0	2014	2014	NCASI statistics on WWTP residuals management go back to 1979, at which point 11% of these residuals was being burned for energy. By 1988, this had increased to 21%.
WWTP residuals — w/o benefits of the displaced fossil fuels (gate-to-gate)	5.9	12.6	2008	2001	

Residual	Years For Emissions from Facility Using Residuals for Energy on an Ongoing Basis to Be Equal to Emissions from a Facility Disposing of These Residuals (Under Typical Scenario)		Year in the Past When Ongoing Practice Would Have Had to Be Initiated for Emissions from the Two Facilities to Be Equal in 2014 (Under Typical Scenario)		Past Industry Practice in Using the Residuals for Energy
	Annual Emissions	Cumulative Emissions	Annual Emissions	Cumulative Emissions	
Paper recycling residuals — w/ benefits of the displaced fossil fuels (cradle-to-energy)	0	0	2014	2014	There are different types of recycling residuals generated by mills using recovered paper. Some of these are combined with WWTP residuals and managed similarly to what is described above; i.e., in 1979 11% of WWTP residuals were burned for energy, increasing to 21% in 1988. OCC rejects, however, are often managed separately. NCASI has published information showing that using recycling residuals for energy started as early as 1975.
Paper recycling residuals — w/o benefits of the displaced fossil fuels (gate-to-gate)	7.7	16.8	2006	1997	
Black liquor — w/ benefits of the displaced fossil fuels (cradle-to-energy)	0	0	2014	2014	Based on AF&PA statistics, in 1971, 35% of the fuel (84% of the biomass) burned at pulp and paper mills was black liquor. By 1980, this had increased to 40% of the fuel (79% of the biomass). Between 1987 and 1999, it varied between 43% and 46% of the fuel (71% to 75% of the biomass).
Black liquor — w/o benefits of the displaced fossil fuels (gate-to-gate)	0	0	2014	2014	
Weighted average of biomass mfg. residuals — w/ the benefits of the displaced fossil fuels (cradle-to-energy)	0.2	0.4	2013	2013	N/A
Weighted average of biomass mfg. residuals — w/o the benefits of the displaced fossil fuels (gate-to-gate)	2.4	5.5	2012	2008	

8.0   UNCERTAINTY AND LIMITATIONS

This section provides further interpretation of the robustness of the results presented above.

8.1   Data Accuracy and Uncertainty

Evaluating data accuracy and uncertainty is an important aspect of LCA studies. An LCA is a complex model made up of thousands of data points and the accuracy of these data can highly affect the results. Analyzing the uncertainty of such a complex model is not straightforward. Techniques such as Monte Carlo analysis can be used to evaluate uncertainty, but an important challenge is the lack of uncertainty data for the different variables that comprise the LCA model. Therefore, in many cases, the robustness of the results and conclusions of LCA studies are assessed using other methods. In this study, the parameters with potential effects on the results were analyzed using sensitivity analyses covering their most probable range of variation and results were discussed given these variations. However, without comprehensive uncertainty data, it was impossible to quantitatively assess the statistical significance of the differences between the compared systems.

The data collection process met the data quality goals as set out in Section 4.4.

8.2   Limitations

The main limitations of this study are summarized in this section. They relate primarily to the conformity of the study with ISO LCA standards (ISO 2006a, b) and to the data used and assumptions made.

8.2.1   ISO Conformity

As mentioned previously, a streamlined LCA methodology was used in this study. As a consequence, it was not possible to fully comply with ISO 14044 requirements for comparative assertions disclosed publicly. The main non-conformances are outlined below.

- Although the assumptions, models and results were reviewed by a committee of stakeholders, no formal external critical review was performed.
- While the Standard requires that for studies intended to be used for publicly disclosed comparative assertions, a sufficiently comprehensive set of impact categories be employed, only two were used in this study, in accordance with the study objective.
- No formal uncertainty analysis was performed.

In addition, the gate-to-gate analyses need to be understood as additional information rather than as an LCA result.

8.2.2   Data and Assumptions

Some of the generic data sets used in this study were not specific to the US, although the study employed a version of these data sets modified to use US electricity production.

The relevant characteristics related to the residuals analyzed in this study are typically quite variable. This variability was analyzed in sensitivity analyses and results were shown for range of characteristic values sufficiently large to cover most of the variability.

The data identified for size reduction were fixed on a per tonne basis and did not account for the extent of size reduction. That said, size reduction was not found to significantly affect the study results.

Several assumptions were made regarding WWTP residuals that could have affected the study results. The main ones are discussed here.

- It was assumed that mechanical dewatering can achieve 40% solids, that this was sufficient for combustion, and that the same level of dewatering was also suitable for transporting them to a landfill disposal site. The main reason for this assumption was that no data were available concerning the energy consumption for additional dewatering. Assuming additional dewatering would have had two main effects on the results. First, this would have decreased the overall performance of the biomass energy system by increasing its consumption of energy and related releases. Second, assuming drier WWTP residuals would have increased boiler efficiency, and thus reduced the quantity of residuals required to produce 1 GJ of energy, which would have resulted in lower benefits when analyzing the results on a per gigajoule basis, but greater benefits on a per tonne of residuals basis.

- It was also assumed that WWTP residuals would be co-fired with bark in a 20:80 ratio. Based on this ratio, a boiler efficiency was calculated. Increasing the share of residuals in the mix burned would have decreased the boiler efficiency, while decreasing their share would have increased the efficiency. The effect of boiler efficiency on the results was discussed immediately above. The relationship between the share of WWTP residuals burned and boiler efficiency is also uncertain. The best available information was used.

Because paper recycling residuals are made up of a mix of a materials that have characteristics similar to WWTP residuals (negative effect on boiler efficiency compared to woody biomass residuals) and plastic (positive effect on boiler efficiency compared to woody biomass residuals), it was assumed that paper recycling residuals would be burned in boilers with the same efficiency as woody biomass residuals at a given water content. Boiler efficiencies for these kinds of material are not known, however. The effect of boiler efficiency on the results was discussed above. Also, OCC rejects were considered to be representative of paper recycling residuals in general. In cases where, for instance, the plastic fraction of other paper recycling residuals is outside the range studied in this study, results would be slightly different. However, a broad range of characteristics were examined in this study to account for that eventuality.

The best available data for energy production using fossil fuels were used. These data were deemed representative of average US conditions. No sensitivity analyses were performed on that part of the modeling. As a consequence, the results of the study cannot be generalized to a broader set of conditions regarding energy production from fossil fuels. Also, it was assumed that the difference in energy requirements for air emissions control would not vary significantly from one fuel to another. If this were not the case, and in particular if the energy penalty for emissions control were lower for natural gas than for biomass, the benefits calculated for scenarios involving natural gas would be reduced. This is not, however, expected to be significant.

The results are very sensitive to landfill and waste decomposition characteristics and these characteristics are very uncertain. Sensitivity analyses were performed to address this issue. Results appear to be robust within the ranges assessed for those characteristics. The analysis of the timing of emissions depends heavily on those landfill characteristics. In the absence of information more specific to forest products manufacturing residuals, USEPA decay rates for municipal landfills were used. These decay rates were derived for a mix of wastes, i.e., not only for woody materials which may degrade more slowly. Therefore, the lower decay rates used in the scenarios are probably more representative of woody materials. Even considering this, the break-even times were short, with the exception of paper recycling residuals that contain a fraction of plastic.

Finally, the results on the ongoing practice analyzes are valid only in the context of two main assumptions: 1) assuming the same quantity and type of energy produced in every years, 2) assuming the same alternative fates and fossil fuel displaced in every year.

9.0   CONCLUSIONS

In this study, the GHG and fossil fuel-related benefits of using woody manufacturing residuals, recycling residuals, and wastewater treatment plant residuals for energy production within the forest products industry were analyzed using life cycle principles and other additional analyses. It was shown that using all types of residuals for energy production produces significant benefits both in terms of reduced fossil fuel consumption and reduced greenhouse gas emissions. This result is valid across a range of system configuration scenarios (boiler type, assumptions about the displaced fossil fuel, the GHG intensity of the electricity grid, and the level of cogeneration at forest products facilities), residual characteristics (e.g., heating value, moisture content), and whether or not the benefits from fossil fuel substitution are considered. These findings hold true whether biogenic CO_2 is included in the analysis or excluded by giving it an emission factor of zero (equivalent to what is sometimes called "carbon neutrality"). The benefits occur without affecting the amount of wood harvested or the amount of wood products produced. It typically takes less than one year before the cumulative emissions in the biomass energy system are lower than those in the corresponding non-use system, with a weighted average (reflecting industry's typical usage rate) of about one year. Even ignoring the benefits of displacing fossil fuel and limiting the analysis to biogenic emissions, the cumulative emissions from the biomass energy systems associated with producing 1 GJ of energy are lower than those from the non-use systems in 0 to 7.7 years, depending on the residual, with a weighted average of 2.4 years.

When considered as an ongoing practice (e.g., ongoing production of 1 GJ energy per year), and when the benefits of displaced fossil fuels are considered, the cumulative impact associated with the typical mix of residuals used for energy in the industry becomes less than that of disposing of the residuals in less than one year. If the benefits of displaced fossil fuels are ignored, the cumulative impact associated with using the typical mix of residuals becomes smaller than the impact associated with disposing of the residuals in less than six years.

The emissions benefits of using manufacturing residuals for energy in the forest products industry are large. Given current practice, the use of manufacturing residuals (including black liquor) in the industry for one year avoids the emission of approximately 218 million tonnes CO_2E, equal to more than three times the annual direct emissions associated with the combustion of fossil fuels in the forest products industry.

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APPENDIX A

ACRONYMS AND NOMENCLATURE

General Acronyms and Nomenclature:

AF&PA: American Forest and Paper Association

AWC: American Wood Council

BC: Base case

BDmT: Bone-dry metric tonne

Bio: Biomass

BioCO$_2$: Biogenic CO_2

Biogenic GHGs: Biogenic CO_2 as well as CH_4 produced from decomposing biomass and CH_4 and N_2O produced in biomass combustion

Biomass energy system: Product system in which the biomass residuals are used for energy production

Break-even time: Number of years required for the cumulative emissions from the non-use system to equal the cumulative emissions from the biomass energy system

CHP: Combined heat and power

CORRIM: Consortium for Research on Renewable Industrial Materials

CO$_2$: Carbon dioxide

CO$_2$E: CO_2 equivalents, i.e., measure for describing how much global warming a given type and amount of greenhouse gas may cause, using the functionally equivalent amount or concentration of carbon dioxide (CO_2) as the reference

Cradle-to-final energy analysis: A cradle-to-final energy analysis can be defined as a specific LCA applied to the production of energy. It generally includes the extraction and production of fuels, their transportation and their combustion to produce energy.

Differential GHGs: Absolute difference in releases of GHGs, including biogenic CO_2 emissions and removals

Eff: Efficiency

EPA: Environmental Protection Agency

FF: Fossil fuel

Non-use system:	Product system in which the fossil fuels are used for energy production and in which an alternative fate for the biomass residuals is considered or in which only the alternative fate of the biomass residuals is considered
Gate-to-gate analysis:	A gate-to-gate analysis can be described as a partial LCA looking at only one value-added process in the entire production chain
GHG:	Greenhouse gas
GJ:	Gigajoule (1 GJ = 0.948 MMBtu)
GWP:	Global warming potential
HHV:	Higher heating value
H&P:	Heat and power
ISO:	International Organization for Standardization
LCA:	Life cycle assessment
LCI:	Life cycle inventory
LCIA:	Life cycle impact assessment
LHV:	Lower heating value
NG:	Natural gas
N/Av.:	Not available
OCC:	Old corrugated containers
OECD:	Organisation for Economic Co-operation and Development
Relative FF CON:	Relative difference in fossil fuel consumption of the biomass energy system compared to the non-use system
Relative Non-Bio CO_2 GHGs:	Relative difference in GHGs, <u>not including biogenic CO_2</u>, of the biomass energy system compared to the non-use system
Removals:	Sequestration or absorption of CO_2 from the atmosphere by the trees
US:	United States
WWTP:	Wastewater treatment plant

System Configuration Scenarios Nomenclature:

Alternative Fate Scenarios

MR1: Landfilling

MR2: Incineration

Boiler Type Scenarios

FB: Fluidized bed boiler

SB: Stoker boiler

Fossil Fuel Scenarios

A: Heat from coal

B: Heat from natural gas

C: US-average electricity

D: Electricity from coal

E: Fossil fuel scenario, electricity from natural gas combined cycle

Size Reduction Scenarios

SR0: Size reduction scenario, no size reduction

SR1: Size reduction scenario, mobile chipper

SR2: Size reduction scenario, stationary chipper

A4

General Nomenclature:

CC: Biogenic carbon content

E_{DC}**:** Usable energy from direct combustion

E_{Turb}**:** Steam to turbine

F_{CCND}**:** Non-degradable carbon content under anaerobic conditions

F_{CH4CB}**:** Fraction of methane captured and burned

F_{CH4OX}**:** Fraction of methane oxidized in landfill covers

k: Decay rate

L: Losses

MCF: Methane correction factor

P: Power to process

Q_R**:** Quantity of residuals required to produced 1 GJ of usable energy

SHP: High pressure steam to process

SMP/LP: Extraction steam to process

WC_R**:** Water content of residuals

From:	Ohrel, Sara
To:	Cole, Jefferson
Sent:	4/10/2014 8:59:26 AM
Subject:	FW: Black liquor fate paper revisions
Attachments:	Black_Liquor_Fate_2-14-14rev so.docx

Sorry, forgot you weren't on her email when I replied.

From: Ohrel, Sara
Sent: Thursday, April 10, 2014 8:59 AM
To: 'Hanks, Katie P.'
Cc: Baker, Justin
Subject: RE: Black liquor fate paper revisions

Looking good. some minor edits/questions in the attached. Can we have a quick chat today (half hour) about this and next steps? I am available at 12-1 and 2-3.

From: Hanks, Katie P. [mailto:kphanks@rti.org]
Sent: Wednesday, April 09, 2014 4:45 PM
To: Ohrel, Sara
Cc: Baker, Justin
Subject: Black liquor fate paper revisions

My revisions to the black liquor paper are attached with my responses (in yellow) in the comment bubbles. We can eliminate the bubbles when you are ready.

I will start looking over the ICF memo, the black liquor Case 3 in the AF1 document, and the NCASI comment from October 2011 relative to Case 3. The information provided in the attached paper did not consider these prior documents.

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

From:	Ohrel, Sara
To:	Justin Baker (justinbaker@rti.org); Robert H. Beach (rbeach@rti.org); Hanks, Katie P.
CC:	Greg Latta; Cole, Jefferson
Sent:	4/8/2014 5:06:17 PM
Subject:	FYI
Attachments:	TO 003_Memorandum_Pulp and Paper Mill Case Study Comparison_03-11-2013 so.docx

FYI: attached is a comparison that ICF did for us between the AF1 case study that looked at black liquor and the NCASI recalculation of the case study using their assumptions. Might be useful in how we think about/frame black liquor.

-deliberative-

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Greg Latta
Sent:	4/8/2014 11:16:30 AM
Subject:	FW: Information on black liquor
Attachments:	Black_Liquor_Fate_2-14-14.docx

another

From: Hanks, Katie P. [mailto:kphanks@rti.org]
Sent: Friday, February 14, 2014 5:15 PM
To: Ohrel, Sara
Cc: Baker, Justin; Beach, Robert H.; Boone, Stephen
Subject: Information on black liquor

Sara,

The attached file is my attempt to shed some light on the kraft pulping process and black liquor generation through a review of documents I had in hand or found easily online.

Ex. 5 - Deliberative

Ex. 5 - Deliberative

Ex. 5 - Deliberative

The attached file is a draft. There is room to build off of this if desired (references need to be cleaned up, etc). Please let me know if you have any questions, or would like for me to continue searching for specific information.

Regards,

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

From:	Ohrel, Sara
To:	Gunning, Paul
CC:	Suzanne Kocchi
Sent:	4/3/2014 3:24:53 PM
Subject:	FW: comments and edits on draft approaches chart
Attachments:	Possible Approaches Chart for Assessment Factor draft 4 3 14 OAP editsv3.docx; Possible Approaches Chart for Assessment Factor draft 4 3 14 OAP editsv3_clean.docx

FYI

From: Ohrel, Sara
Sent: Thursday, April 03, 2014 3:24 PM
To: Montanez, Jessica; Mangino, Joseph; Brooks, MichaelS; Wheeler, Carrie; Kornylak, Vera S.; Santiago, Juan; Doster, Brian; Scott Jordan (Jordan.Scott@epa.gov); Elliott Zenick (Zenick.Elliott@epa.gov)
Cc: Suzanne Kocchi; Bill Irving; Allen Fawcett; Cole, Jefferson
Subject: comments and edits on draft approaches chart

Hello everyone,

Attached you will find our comments on the draft approaches chart (2 versions; one is tracked changes, one clean). It looks like a lot, but many changes are simply rearranging options so we could streamline it in order to better understand it. We also added

Ex. 5 - Deliberative

We hope this helps, happy to discuss.
Best,
Sara

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Hanks, Katie P.
To:	Ohrel, Sara
CC:	Jefferson.cole@Epa.gov; Baker, Justin
Sent:	3/28/2014 4:25:52 PM
Subject:	Combined draft documents
Attachments:	DRAFT Framework main report 2 25 14_clean_Boone_Final_Comments.docx; DRAFT Framework_Master_3-28-14.docx; Framework_Comments_RTI_3-28-14.docx

Sara,

Attached are three draft, deliberative framework documents. The first file combines the EPA comments into one document. The second file contains the RTI economics team comments. The third file is Stephen Boone's comments which touch on policy application.

Please let us know if you want RTI to assist with addressing these comments beyond compiling them.

Katie Hanks
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
(919) 316-3732
(919) 541-7155 (fax)

This communication contains is draft, deliberative (FOIA exempt) material that is not for distribution.

From:	Ohrel, Sara
To:	Justin Baker (justinbaker@rti.org)
Sent:	3/28/2014 11:11:26 AM
Subject:	FW: Meeting on Biogenic Carbon Accounting Fri 3/28 11:45am
Attachments:	Letter to J Santiago re Def Manufacturing Residuals 022114 FINAL.pdf

American Forest & Paper Association

February 21, 2014

Mr. Juan Santiago
U.S. Environmental Protection Agency
109 T.W. Alexander Drive
Mail Code: C504-01
Research Triangle Park, NC 27709

Re: Definition of Forest Product Manufacturing Residuals

Dear Mr. Santiago:

In December, 2013, AF&PA staff discussed with you the timing and development of EPA's Biogenic CO_2 Accounting Framework and the definition of manufacturing residuals. Following up on that discussion as well as the NCASI report we provided to you and your staff, "Greenhouse Gas and Fossil Fuel Reduction Benefits of Using Biomass Manufacturing Residuals for Energy Production in Forest Products Facilities", we would like to provide for your consideration a definition of the "forest products manufacturing residuals" that could be incorporated into the Framework and permitting regulations.

As you know, the forest products industry uses biomass residuals from the manufacturing process for its primary energy source. Unlike power plants and other biomass energy facilities, the creation and use of biomass energy in forest products mills is integral and incidental to the manufacture of products such as pulp, paper, packaging and wood products. Pulp mills, integrated paper mills and wood products mills convert biomass residuals to energy for manufacturing bio-based products. To the extent feasible, the wood biomass entering the mills is used to create these higher value products. The use of the residuals for energy is a highly sustainable use of those materials. Indeed, it would be unsustainable not to use the residuals for energy. In addition, recognizing that combustion of forest products manufacturing residuals for energy as carbon neutral helps to promote the use of renewable energy.

AF&PA proposes that EPA use the following definition for "forest products manufacturing residuals" in the Biogenic CO_2 Accounting Framework and corresponding regulations:

"Forest products manufacturing residuals" are defined as forest-derived biomass from pulp and paper mills, wood products manufacturing facilities, and downstream manufacturing facilities including, but not limited to:
- *spent pulping liquors (e.g., black liquor, red liquor, liquor solids) and pulping by-products and substances (e.g., rectified methanol, black liquor soap, red oil, lignin);*
- *woody manufacturing residuals, such as:*

- *wood product process residuals (e.g., bark, sawdust, shavings, sander dust, resinated wood residuals, veneer residuals, slabs, cutoffs, knots, woody residuals from air emission control systems, manufactured wood residuals (e.g., furniture, crate and pallet plant residuals);*
  - *pulping, paper, and converting process residuals (e.g., bark, knots, shives, non-recoverable trim and broke);*
  - *off-specification materials; reinjection char (unburnt biomass); paper machine cleaner, screening and other rejects; and*
  - *similar residuals;*
- *paper recycling residuals (e.g., materials removed from recovered paper and paperboard during the recycling process, such as non-recyclable fiber or old corrugated containers rejects); and*
- *wastewater and process water treatment plant residuals.*

We believe that this definition captures the various categories of manufacturing residuals that are most commonly used by the forest products industry for energy. To be clear, we believe other types of biomass materials should also be considered carbon neutral but the focus of this letter is to provide you the above definition for manufacturing residuals from forest products.

If you would like to further discuss this issue, please contact me at Paul_Noe@afandpa.org or 202-463-2777 or Linda Tsang at Linda_Tsang@afandpa.org or 202-463-2752.

Respectfully submitted,

Paul Noe
Vice President, Public Policy

cc: Joseph Goffman
     Sarah Dunham
     Anna Wood
     Paul Gunning
     Sara Ohrel

From:	Ohrel, Sara
To:	Cole, Jefferson
Sent:	3/27/2014 9:56:40 AM
Subject:	secondary old stuff
Attachments:	TO 003_DRAFT_Appendix K_02-01-2013.docx

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
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Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Swanson, Nicholas; Culligan, Kevin
CC:	Cole, Jefferson
Sent:	3/24/2014 11:13:57 AM
Subject:	FW: Remaining Draft Technical Appendices for Assessment Framework - DELIBERATIVE
Attachments:	DRAFT Appendix B Time 3 20 14_clean.docx; DRAFT Appendix D Feedstock Categories 3 20 14_clean.docx; DRAFT Appendix F Process Attributes 3 19 14v2 clean.docx; DRAFT Appendix G Leakage 3 20 14_clean2.docx; DRAFT Appendix H Anticipated Baselines background 3 20 14_Cleaner2.docx

Hello Nick and Kevin,

We were recently asked to send all the remaining appendices for the biogenic assessment report 'as is' to Anna's group (attached). We are continuing to work on these, but wanted to share them/give you the status update as FYI. Please feel free to take a look but these appendices are subject to (in some cases significant) change.

Best,

Sara

From: Ohrel, Sara
Sent: Thursday, March 20, 2014 10:08 PM
To: Wood, Anna; Santiago, Juan; Montanez, Jessica; Kornylak, Vera S.; Wheeler, Carrie; Mangino, Joseph; Brooks, MichaelS; Doster, Brian; Scott Jordan (Jordan.Scott@epa.gov); Elliott Zenick (Zenick.Elliott@epa.gov)
Cc: Cole, Jefferson; Allen Fawcett; Suzanne Kocchi; Bill Irving; Gunning, Paul
Subject: Remaining Draft Technical Appendices for Assessment Framework - DELIBERATIVE

Hello everyone,

Attached you will find the rest of the draft technical appendices of the assessment framework. As before, we are sharing these appendices now 'as is', so it is important to note that many of these appendices (and the illustrative values in them) are subject to change. As such, please feel free to send us any general comments or questions on these appendices as you review them.

The chart below gives a list of the various draft appendices and their status for your convenience (letters are not sequential due to consolidation):

IPCC Approach to Accounting for Anthropogenic Greenhouse Gas Emissions	A	Previously sent
Treatment of Temporal Scale	B	Attached (subject to change)
Treatment of Spatial Scale	C	Previously sent
Feedstock Categorization and Definitions	D	Attached (subject to change)
Discussion of Leakage	G	Attached (subject to change)
Discussion of Process Attributes	H	Attached (subject to change)
Retrospective Reference Point Baseline: Methodology and Results for Landscape Attributes	I	Previously sent
Case Studies under a Retrospective Reference Point Baseline	J	Previously sent
Anticipated Baselines: Background and Key Modeling Considerations	K	Attached (subject to change)

Future Anticipated Baseline: Baseline Construction Methodology and Results	L	Previously sent
Case Studies under a Future Anticipated Baseline	M	Previously sent
Discussion of Results from Both Baselines with Sensitivities	N	Previously sent
Accounting for Biogenic CO2 Emissions from Waste-Derived Feedstocks	O	Previously sent
General Algebraic Representation of Net Biogenic Emissions and Biogenic Assessment Factor Equations	YY	Previously sent

Best wishes,
Sara on behalf of Team Biomass

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Cole, Jefferson
To:	Cole, Jefferson; Ohrel, Sara
CC:	Baker, Justin; greg.latta@oregonstate.edu
Sent:	3/20/2014 7:01:58 PM
Subject:	RE: Process attributes app *Deliberative Draft*
Attachments:	Appendix F process attributes 3 19 14v2 clean.docx; Appendix F process attributes 3 19 14v2_jsb_jc.docx

Disregard that first email. Resending with the example at the end re-inserted (which I had deleted), and putting in an "Under Construction" flag at the top.

So, use these instead.

Jeff

From: Cole, Jefferson
Sent: Thursday, March 20, 2014 6:53 PM
To: Ohrel, Sara
Cc: 'Baker, Justin'; greg.latta@oregonstate.edu
Subject: Process attributes app *Deliberative Draft*

Folks,

I've taken Justin's version, made some more edits, and then cleaned it up. I present both the messy and clean versions for our records.

Best,

Jeff

Jefferson Cole
Economist
Climate Change Division
U.S. EPA
202.343.9671
cole.jefferson@epa.gov

From:	Cole, Jefferson
To:	Ohrel, Sara
CC:	Baker, Justin; greg.latta@oregonstate.edu
Sent:	3/20/2014 6:52:41 PM
Subject:	Process attributes app *Deliberative Draft*
Attachments:	Appendix F process attributes 3 19 14v2 clean.docx; Appendix F process attributes 3 19 14v2_jsb_jc.docx

Folks,

I've taken Justin's version, made some more edits, and then cleaned it up. I present both the messy and clean versions for our records.

Best,

Jeff

Jefferson Cole
Economist
Climate Change Division
U.S. EPA
202.343.9671
cole.jefferson@epa.gov

From:	Baker, Justin
To:	Ohrel, Sara; Cole, Jefferson
CC:	greg.latta@oregonstate.edu
Sent:	3/20/2014 3:34:37 PM
Subject:	Appendix F
Attachments:	Appendix F process attributes 3 19 14v2_jsb.docx

Dear Sara and Jeff,

Here is an updated draft of Appendix F. I think this is very much still a work in progress, and some of the examples need to be updated (for instance, ⌐ ‾ ¬ **Ex. 5 - Deliberative**
Ex. 5 - Deliberative

I think I was able to ⌐ ‾ ‾ ‾ ‾ ‾ ‾ ‾ ‾ **Ex. 5 - Deliberative** ‾ ‾ ‾ ‾ ‾ ‾ ¬ but please let me know if it makes sense. I left my track changes and comments in for now, so it will need to be scrubbed.

Thanks,
Justin

From:	Cole, Jefferson
To:	Ohrel, Sara
Sent:	3/19/2014 6:42:15 PM
Subject:	Feedstock Categorization Appendix
Attachments:	Appendix D - Feedstock Cat - 2014.01.30 - JC Edits.docx; Appendix D - Feedstock Categories - 2014.03.19.docx; Appendix M - Secondary Feedstocks - 2014.01.30 - Edits JC.docx

Sara,

Here is my latest draft of the feedstock categorization appendix. I've labeled the file with today's date.

Just to be clear what I've done:
- I took the old version, accepted almost all of the changes, but left nearly all comments in (I deleted a couple irrelevant ones).
- From there, I went through the document and made edits. So, the only track changes edits you see in this version are the ones I made today. I also made a few new comments.
- I tried to be consistent with the main document as it is now.

My biggest comment is **Ex. 5 - Deliberative**

Ex. 5 - Deliberative

For your reference, I've included the old versions of the feedstock categorization and secondary feedstock app since there are several comments and track changes in those files.

Overall, this appendix could still use some work, but I think I mostly have it in a place where we can share. Let me know if you have any questions or need anything.

Have a good night,

Jeff

Jefferson Cole
Economist
Climate Change Division
U.S. EPA
202.343.9671
cole.jefferson@epa.gov

From:	Jordan, Scott
To:	Ohrel, Sara
CC:	Doster, Brian; Zenick, Elliott
Sent:	3/12/2014 9:03:41 AM
Subject:	FW: Draft biogenic assessment framework - OGC Comments so far
Attachments:	Biogenic CO2 DRAFT Framework main report 2 25 14_clean SJJ notes 2 25 14+3 6 14 (2) + bld.docx

Sara -

Attached are OGC's comments so far. The attached document shows Brian's comments on the Executive Summary and Introduction section on top of the comments that I provided to you last week. We will provide any additional OGC comments as soon as we can, but wanted to provide these to you now.

Scott Jordan
202-564-7508

From:	Flugge, Mark
To:	Ohrel, Sara
CC:	Cole, Jefferson
Sent:	3/11/2014 4:25:49 PM
Subject:	FW: Draft biogenic assessment framework report for your review - deliberative
Attachments:	EPA DRAFT Framework main report 2 25 14_clean.docx

Hi Sarah: please find attached Gregg's current mark-up of the draft.

Best regards,
Mark

___

From: Gregg Marland [mailto:marlandg@appstate.edu]
Sent: Tuesday, March 11, 2014 3:50 PM
To: Flugge, Mark
Subject: RE: Draft biogenic assessment framework report for your review - deliberative

Mark, as I told you, I am having real problems with this draft. Let me share with you the portion of text that I have marked up and you will get a specific sense of my issues.

Gregg

___

From: Flugge, Mark [mailto:Mark.Flugge@icfi.com]
Sent: Friday, February 28, 2014 10:04 AM
To: Gregg Marland (marlandg@appstate.edu)
Cc: Sara Ohrel (Ohrel.Sara@epa.gov); Jefferson Cole (Cole.Jefferson@epa.gov)
Subject: FW: Draft biogenic assessment framework report for your review - deliberative

From: Ohrel, Sara [mailto:Ohrel.Sara@epa.gov]
Sent: Tuesday, February 25, 2014 8:21 AM
To: Flugge, Mark
Cc: Cole, Jefferson
Subject: Draft biogenic assessment framework report for your review - deliberative

Hi Mark,

Attached is our draft main report of the framework for your review. We can discuss the allotted hours for your review and potential review by certain members of the ITT when we chat next. Until our discussion, please do not share or cite the report of its contents with anyone at this point.

Unfortunately I have another meeting at the time of our regular call now, so can we please move that to Thursday afternoon sometime between 1 and 4pm?

Thank you!
Sara

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
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Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

From:	Ohrel, Sara
To:	Cole, Jefferson
Sent:	3/10/2014 11:52:34 AM
Subject:	Fw: Materials for Monday's Meeting
Attachments:	Draft - NAFO Legal Authority White Paper 3.7.14.doc; FORISK US_Bioenergy_Markets FINAL 6-2013.pdf; NAFO Wood Bioenergy_Forestland Owners FINAL 20140212.pdf; Regional Approach to BCA Using FIA Data.pptx

From: Browne, Cynthia
Sent: Monday, March 10, 2014 9:43:57 AM
To: Dunham, Sarah; Wood, Anna; Santiago, Juan; Kornylak, Vera S.; Gunning, Paul; Irving, Bill; Ohrel, Sara
Subject: FW: Materials for Monday's Meeting

FYI -

From: Dave Tenny [mailto:dtenny@nafoalliance.org]
Sent: Friday, March 07, 2014 6:16 PM
To: Goffman, Joseph
Cc: Browne, Cynthia; Chip Murray; Karisa Smith
Subject: Materials for Monday's Meeting

Hi, Joe – thanks for the good meeting today. Attached are the following read ahead materials for Monday's meeting:

1. Updated legal/administrative record analysis (fixing the typos Roger mentioned)
2. NCASI slides on carbon per acre method for determining BAF's
3. FORISK white paper on biomass consumption and landowner behaviors (this is the one I already sent you, but I am including it here for convenience)
4. FORISK white paper on bioenergy markets (this is the paper I referenced today addressing some of the RPA predictions)

Our plan is to split the meeting time between the first two attachments with about 10 min. of presentation for each followed by Q&A. I will reference attachments 3 and 4 during the meeting much like I did today, but we won't dwell on them.

Thanks, Joe. Have a great weekend.

Dave

David P. Tenny
President and CEO
National Alliance of Forest Owners
122 C Street, NW, Suite 630
Washington, D.C. 20001
Office: (202) 747-0739
Fax: (202) 824-0770
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dtenny@nafoalliance.org
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EPA'S CLEAR LEGAL AUTHORITY AND DISCRETION TO DIFFERENTIATE BIOGENIC CO$_2$ EMISSIONS FROM OTHER GHG EMISSIONS UNDER THE CLEAN AIR ACT.

Table of Contents

Introduction

The Clean Air Act ("CAA") and supporting case law provide EPA clear legal authority to distinguish between carbon dioxide ("CO_2") emissions from biomass combustion ("biogenic CO_2 emissions") and greenhouse gas ("GHG") emissions from other sources, and thus exclude biogenic CO_2 emissions from CAA regulatory and permitting regimes or, at a minimum, establish a differential regulatory scheme for biogenic CO_2 emissions. In particular, EPA has significant authority and discretion to not bring such emissions within the CAA framework at the outset because CO_2 emissions from biogenic sources do not increase net atmospheric CO_2 concentrations and, therefore, do not cause or contribute to climate change. Thus, EPA need not reach the question of how to treat such emissions under the Prevention of Significant Deterioration ("PSD") permitting program, as there is ample authority for not bringing such emissions within the framework of PSD—if not the CAA—in the first instance, given the lack of any adverse affect of such emissions on the climate.[1] However, even if EPA were to include biogenic CO_2 emissions in the PSD permitting program, there are established grounds for treating biogenic CO_2 emissions differently from fossil fuel CO_2 emissions. This paper is intended to summarize a range of legal theories that offer flexibility to EPA to differentiate biogenic CO_2 emissions from other GHG emissions as it seeks to implement its ultimate policy decision regarding the treatment of biogenic CO_2 emissions under the PSD and Title V permitting programs. In addition, it will provide a summary of the scientific evidence supporting differential treatment for biogenic CO_2 emissions.

As described below, EPA historically has excluded certain air emissions from the PSD and other CAA programs—even when pollutants that comprise such emissions are otherwise regulated in some contexts. More recently, in the context of GHG regulations, EPA has relied on a variety of regulatory approaches to distinguish between GHGs, completely excluding some from regulation, while providing differential treatment for others. The case for declining to bring biogenic CO_2 emissions within the PSD program (or at a minimum providing differential treatment for such emissions) is even stronger than this past precedent, given the lack of any net adverse effect on the climate from such emissions. In making such a decision, EPA can also properly consider any net GHG benefits that utilizing biomass for power generation or industrial processes provides vis-à-vis other fuels or feedstocks.

This paper is divided into four sections. Section I explains the legal basis for declining to regulate biogenic CO_2 emissions under the CAA at this time because those emissions do not adversely affect the environment. In the alternative, Section II explains that even if EPA were to conclude that it has the authority to consider the regulation of biogenic CO_2 emissions to some extent, it retains significant authority and discretion to exclude or provide different treatment for such emissions. The section provides several legal bases on which EPA could justify treating biogenic and fossil CO_2 emissions differently. Section III explains that the recent decision in *Center for Biological Diversity*, 722 F.3d 401 (D.C. Cir. 2013) does not foreclose EPA's discretion to provide different and preferential treatment for biogenic CO_2 emissions on a

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[1] This white paper focuses on the PSD permitting program as an example for how EPA has solid legal authority to treat biogenic CO2 emissions differently from other GHG emissions. However, the rationales, justification, and support provided here apply as well to other regulatory programs for addressing GHG emissions under the CAA, and also provide policy and technical support for making such distinctions in other government programs.

1

permanent basis. Finally, Section IV provides an expanded summary of the key factual bases for differentiating between biomass emissions and other GHG emissions in CAA permitting as well as a brief description of the scientific literature supporting each point.

I.   EPA Has Legal Authority to Conclude that the Clean Air Act Does Not Authorize EPA to Regulate Emissions Which Do Not Adversely Affect the Environment.

A core principle underlying much of EPA's regulatory authority under the CAA is that EPA shall regulate only air pollutants that endanger human health or public welfare. Unlike CO_2 emissions from fossil sources, emissions from the combustion of biomass do not increase net atmospheric levels of CO_2.[2] Domestic forests constitute the nation's leading carbon sink. EPA itself has recognized the lack of any adverse effect from biogenic CO_2 emissions in other contexts. For example, EPA's Mandatory Reporting of Greenhouse Gases Rule distinguishes biogenic CO_2 from other emissions. *See generally* 75 Fed. Reg. 56,260 (Oct. 30, 2009). Likewise, in the Renewable Fuel Standard 2 rulemaking, EPA explained that "[f]or renewable fuels, tailpipe emissions only include non-CO_2 gases, because the carbon emitted as a result of fuel combustion is offset by the uptake of biogenic carbon during feedstock production." 75 Fed. Reg. 14,669, 14,787 (March 26, 2010). In addition, the Department of Energy and virtually every government agency in the world to take up the issue have similarly recognized the lack of any adverse effect from biogenic CO_2 emissions.[3] *See also* NAFO's submission on EPA's Call for Information.

Because biogenic CO_2 emissions have no adverse effect on the climate and in the absence of specific direction from Congress to regulate such emissions under the CAA, EPA could reasonably conclude that it lacks a basis for regulating them in the first instance. In the Endangerment Finding, EPA specifically concluded that that the combined emissions of GHGs

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[2] As described more fully in Section IV, and in numerous other contexts, net fluxes of biogenic CO_2 to the atmosphere from the combustion of biomass in the United States are, at a minimum, "carbon neutral" in that any CO_2 emissions associated with the combustion of biomass are offset completely by the significant role domestic forests play in sequestering carbon as the nation's leading carbon sink. Thus, when viewed over appropriate time and spatial scales, the combustion of biomass for energy produces significant GHG emissions reductions in comparison to fossil fuel alternatives. As long as domestic forest carbon stocks are stable or increasing, as they are today, the combustion of forest-based biomass for energy will not increase net atmospheric CO_2 concentrations, regardless of the source. In fact, strong demand for forest products—including biomass for energy—has been shown to increase, rather than decrease, forest carbon stocks through increased investments by forest owners. Thus, even under high-demand scenarios, biomass energy demand can be met without significantly affecting markets for high-value timber products. Further, use of certain biomass feedstocks for energy—including harvest residues, mill residuals, and biomass derived from thinning treatments and timber stand management—offer significant GHG reduction benefits because their combusion typically has a *de minimis* impact on overall atmospheric carbon.

[3] DOE, *Technical Guidelines: Voluntary Reporting of Greenhouse Gases (1605(b)) Program* (January 2007) at 77 ("Reporters that operate vehicles using pure biofuels within their entity should not add the carbon dioxide emissions from those fuels to their inventory of mobile source emissions because such emissions are considered biogenic and the recycling of carbon is not credited elsewhere."); *IPCC Guidelines for National Greenhouse Gas Inventories,* Prepared by the National Greenhouse Gas Inventories Programme, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan: IPCC National Greenhouse Gas Inventories Programme (2006); Commission Regulation (EU) No. 601/2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council, Article 38.2 (The emission factor of biomass shall be zero."), *available at* http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:181:0030:0104:EN:PDF.

2

from new motor vehicles and new motor vehicle engines cause and contribute to air pollution that endangers public health and welfare. EPA reached this conclusion after noting that fossil fuel GHG emissions associated with these sources represented 23 percent of total U.S. emissions of well-mixed GHGs. 74 Fed. Reg. 66,496, 66,540 (Dec. 15, 2009).[4] Because they do not increase net atmospheric CO_2 concentrations, *see infra* Section IV, biogenic CO_2 emissions are fundamentally different from GHGs emitted from fossil fuel sources regulated under Section 202(a) of the CAA. Biogenic CO_2 emissions do not contribute to climate change and, therefore, do not cause or contribute to the endangerment of public health or welfare. Thus, EPA could reasonably conclude that biogenic CO_2 emissions should be excluded from the scope of its CAA regulatory authority based on the lack of any adverse effects.[5]

II.   EPA Has Substantial Discretion in Applying the Clean Air Act to Biogenic CO_2 Emissions and in Implementing PSD and Title V Permitting Programs.

In its landmark *Massachusetts v. EPA* decision, the Supreme Court recognized from the outset that EPA has significant discretion regarding the scope of climate change regulations. While the Supreme Court held that EPA has the authority to regulate GHG emissions from new motor vehicles based on the Court's finding that GHGs fit within the CAA's definition of "air pollutant," the Court also made clear that EPA's determination as to when and how such regulation should proceed is within the discretion of the Agency. *Massachusetts v. EPA*, 549 U.S. 497, 528-29, 533 (2007). "[A]n agency has broad discretion to choose how best to marshal its limited resources and personnel to carry out its delegated responsibilities." *Id.* at 527 (citing *Chevron U.S.A., Inc. v. Natural Resources Defense Council, Inc.*, 467 U.S. 837, 842-845 (1984)); *see also Am. Coke & Coal Chems. Inst. v. EPA*, 452 F.3d 930, 941-42 (D.C. Cir. 2006) ("The court owes particular deference to EPA when its rulemakings rest upon matters of scientific and statistical judgment within the agency's sphere of special competence and statutory jurisdiction.").[6]

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[4] EPA's assessment of motor vehicle GHG emissions as a share of United States GHG emissions specifically excluded biogenic CO_2 emissions because it was based on the United States Greenhouse Gas Inventory. *See* 74 Fed. Reg. at 66,539 n.41 and 66,540; Inventory of U.S. Greenhouse Gas Emissions and Sinks (April 2009) p. 2-5 Table 2-1 n. b and p. 3-1 (excluding biogenic CO_2 emissions based on principles of carbon neutrality). The 2009 Inventory states at page 3-1: "Carbon dioxide emissions from [combustion of biomass and biomass-based fuels] are not included in national emissions totals because biomass fuels are of biogenic origin. It is assumed that the C released during consumption of biomass is recycled as U.S. forest and crops regenerate, causing no net addition of CO_2 to the atmosphere." *See also EPA's Response to Public Comments, Volume 9: The Endangerment Finding* (EPA-HQ-OAR-2009-0171-11676) at 6 (finding that motor vehicle emissions contribute to endangerment does not address biomass burning).

[5] As explained in Section IV, *infra*, this conclusion would be based on the fact that biogenic CO_2 emissions are offset by the sequestration of atmospheric CO_2 by domestic forests. If, at some later date, EPA determined that carbon stocks were no longer stable or increasing, it could revisit the conclusion that biogenic CO_2 emissions from forest stocks do not adversely affect the environment and, if necessary, apply the legal theories described in Section III, *infra*, to determine how biogenic CO_2 emissions should be addressed under the PSD and Title V permitting programs.

[6] Courts specifically have affirmed EPA's discretion regarding the timing and approach to the regulation of GHGs following the Court's decision in *Massachusetts v. EPA*. In rejecting a petition to compel the regulation of GHGs after the *Massachusetts* decision, Judge Tatel observed that "nothing in section 202, the Supreme Court's decision in

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In the Tailoring Rule and related regulations, EPA surgically exercised such discretion to limit the scope and reach of GHG regulation under the CAA. First, EPA specifically defined the precise "greenhouse gases" that are "subject to regulation" as set forth in that rulemaking. *See* 75 Fed. Reg. at 31,606. EPA limited its definition of "greenhouse gases" to "the aggregate group of six" chemicals and excluded other chemicals that may also have climate impacts. *Id.* Second, EPA invoked a series of administrative law doctrines to increase the emissions thresholds for GHGs far beyond those of conventional pollutants regulated under the PSD program. *See, e.g., id.* at 31,533 (asserting authority "to depart[] from a literal interpretation of statutory provisions"). As a result of these regulatory thresholds, a significant number of sources are excluded from the PSD and Title V permitting programs. EPA's discretion is further supported by its past practice in other contexts. For example, EPA has long differentiated biogenic CO_2 emissions from fossil fuel CO_2 emissions in its Inventory of U.S. Greenhouse Gas Emissions and Sinks. Likewise, EPA has relied on a variety of administrative law doctrines and other procedures to exclude certain emissions and air pollutants from regulation under the CAA or to distinguish between different types of regulated emissions. The remainder of this section outlines the legal theories and doctrines that EPA could rely upon to exclude biogenic CO_2 emissions from the PSD and Title V permitting programs or, at a minimum, distinguish between biogenic and fossil fuel CO_2 emissions in a manner that recognizes the substantial climate benefits of biomass combustion when compared to fossil fuel alternatives.

A.   Exclusion of *De Minimis* Emissions

When establishing PSD regulations, EPA has routinely exercised its discretion to avoid bringing certain air pollutants within the reach of the PSD program. In *Alabama Power Co. v. Costle*, 636 F.2d 323, 400 (D.C. Cir. 1979), the D.C. Circuit recognized EPA's discretion, in administering the CAA's provision requiring PSD review for any "modification" of a major emitting facility, "to exempt from PSD review some emission increases on grounds of *de minimis* or administrative necessity." The Court explained that such an exemption was justified when regulation would "yield a gain of trivial or no value." *Id.* at 361.

Invoking similar grounds, EPA has limited PSD permitting to those pollutants that are "subject to regulation" under the CAA, although the statute applies the PSD permitting requirements to "any pollutant." *See Coalition for Responsible Regulation, Inc. v. EPA*, 684 F.3d 102, 134-35 (D.C. Cir. 2012) (*per curiam*) (finding that the CAA does not require EPA to regulate an air pollutant that EPA has determined to be harmless); *see also Alabama Power*, 636 F.2d at 352 n.57. Likewise, even though the CAA may be read to require PSD permitting for any change to a major source that increases emissions of any air pollutant by any amount, *see* CAA §§ 111(a)(4), 169(2)(C), EPA has limited the permitting requirements to modifications that

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Massachusetts v. EPA, or our remand order imposes a specific deadline by which EPA must determine whether a particular air pollutant poses a threat to public health or welfare." *Commonwealth of Massachusetts v. EPA*, No. 03-1361, separate statement of Tatel, J. concurring in part and dissenting in part from denial of petition, June 26, 2008, at 1. Similarly, the Northern District of California also rejected an argument that EPA is compelled to regulate all GHGs following *Massachusetts*. *S.F. Chapter of A. Philip Randolph Inst. v. EPA*, 2008 U.S. Dist. LEXIS 27794 at *10-11 (N.D. Cal. Mar. 28, 2008). Consistent with the D.C. Circuit's conclusion, the California court recognized that "[t]he Supreme Court was careful not to place a time limit on the EPA, and indeed did not even reach the question whether an endangerment finding had to be made at all."

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result in a "significant" net increase in actual emissions. *See* 40 C.F.R. §§ 52.21(b)(2)(i), 52.21(i); *see also United States v. DTE Energy Co.*, 711 F.3d 643, 645 (6th Cir. 2013).[7] For example, carbon monoxide emissions increases of up to 99 tons per year are considered insignificant (or *de minimis*) under EPA's implementing regulations. 40 C.F.R. § 52.21(b)(23)(i); *see also* 45 Fed. Reg. 52,676, 52,705-09 (Aug. 7, 1980) (setting significance levels for PSD permitting programs based on *de minimis* exception). Thus, EPA has a long-standing policy of applying the *de minimis* doctrine to exclude from regulation under the PSD and Title V permitting programs those sources whose emissions increases are deemed insignificant from an air quality perspective, despite the fact that the literal language of the CAA requires permits for *any* emissions increase. *See* 40 C.F.R. § 52.21(b)(23)(i) and (j)(2); 45 Fed. Reg. at 52,722; *Alabama Power*, 636 F.2d at 405.[8]

EPA would be justified in applying a *de minimis* exception for biogenic CO_2 emissions. As explained above, CO_2 emissions from the combustion of biomass are part of the natural carbon cycle and, as a result, do not result in any net increase in atmospheric CO_2 concentrations.[9] Thus, as long as forest carbon stocks are stable or increasing and carbon sequestration is sufficient to offset biogenic CO_2 emissions, the emissions associated with biomass energy can be considered insignificant or *de minimis* from a climate perspective.

B.   Exclusion of Individual Constituents from Pollutant Categories

In cases where EPA defines and regulates a category of pollutants—as it has done for GHGs—the Agency has repeatedly exercised its discretion by distinguishing between individual constituents and excluding those that have negligible environmental impacts. For example, EPA excludes emissions of certain volatile organic compounds ("VOCs") from otherwise applicable PSD permitting requirements. *See* 40 C.F.R. § 51.100(s); *see also* 40 C.F.R. §§ 52.21(b)(2)(ii) and 52.21(b)(30). Despite the fact that these compounds are both "volatile" and "organic" and, therefore, meet EPA's definition of VOCs, they are excluded from regulation because they do not cause environmental impacts. *See* 40 C.F.R. § 51.100(d); 57 Fed. Reg. 3,941, 3,943-44 (Feb. 3, 1992) (disagreeing with comment that definition exceeded EPA's statutory authority and asserting that "it is an administrative necessity and reasonable to define VOC to include all organic compounds except those EPA has determined to be negligibly reactive"). Notably, EPA has excluded these volatile organics from the PSD permitting program and other CAA regulations, not based on an analysis of their direct effects on human health and welfare, but

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[7] Relying on a similar legal theory, EPA has also excluded routine maintenance, repair, and replacement ("RMRR") from triggering New Source Review program requirements. *See Wisconsin Electric Power Co. v. Reilly*, 893 F.2d 901, 905 (7th Cir. 1990) (EPA adopted exclusion for RMRR to avoid regulating "the most trivial activities"); *see also* 40 C.F.R. parts 51-52.

[8] In addition, the *Chevron* decision also addressed EPA's discretion to define the scope of CAA permitting programs, overturning the D.C. Circuit decision that failed to defer to EPA's interpretation of what constitutes a "stationary source" subject to special permitting conditions in nonattainment areas. *Chevron, U.S.A., Inc. v. NRDC*, 467 U.S. 837, 841-42 (1984).

[9] Likewise, CO_2 emissions from fermentation of biomass or from microbial treatment of wastewater containing bio-materials are part of the natural carbon cycle and, hence, do not result in a net increase in atmospheric CO_2 concentrations.

rather based on their lack of contribution, once emitted and mixed with other gases in the environment, to the formation of ground-level ozone through photooxidation.

Likewise, EPA has distinguished among different categories of particulate matter ("PM") based on differences in environmental and public health impacts. *See Alabama Power*, 636 F.2d at 369 n.131 ("EPA has discretion to define the pollutant termed 'particulate matter' to exclude particulates of a size or composition determined not to present substantial public health or welfare concerns."). Thus, EPA has distinguished between fine and coarse PM and established distinct significance levels for particulate matter smaller than 10 microns in diameter and smaller than 2.5 microns in diameter based on the particle size's impact on public health. 40 C.F.R. § 52.21(b)(23)(i).

In addition, EPA has already relied on this regulatory approach to limit the GHGs that are subject to regulation under the CAA. In the Tailoring Rule and other GHG regulations, EPA exercised its discretion to limit the scope and reach of its GHG regulations by specifically defining the pollutants that qualify as "greenhouse gases." EPA chose to limit its definition of "greenhouse gases" to "the aggregate group of six" specified chemicals and excluded other chemicals that also have climate impacts. *See* 75 Fed. Reg. 25,324, 25,397 (May 7, 2010) (identifying the six compounds as "the primary greenhouse gases of concern"); *id.* at 25,398-99 (describing those six compounds as a "single air pollutant"). EPA limited the pollutant GHG to these six compounds despite its findings that they only account for 75% of total anthropogenic heating. 74 Fed. Reg. at 66,517, 66,520 (excluding other gases because they are not thought to be a primary driver of radiative heating, or because their climate impact is unknown). Further, after identifying these six compounds as the single pollutant, GHGs, EPA only elected to regulate emissions of four of the six compounds in the light-duty vehicle rule. *Id.* at 25,396-97. Likewise, in the proposed NSPS rule for power plants, EPA asserts that it is regulating the air pollutant GHGs, but is only establishing emissions limits for a single compound, CO_2. 79 Fed. Reg. 1430, 1455 ("The fact that we are not regulating the other five GHGs does not mean that we are required to identify the air pollution as CO_2 alone rather than the mix of six GHGs.").

This existing precedent under the CAA—and specifically with respect to GHGs—establishes EPA's regulatory authority to differentiate between certain compounds and exclude some from regulation based on different environmental and public health impacts. As a result, EPA could exercise its discretion to amend its existing regulations to differentiate or exclude from regulation biogenic CO_2 emissions. For example, as it did in the light-duty vehicle rule and the proposed NSPS for power plants, EPA could simply exclude biogenic CO_2 emissions, even though they may technically fall within the broad definition of GHGs. EPA could also redefine its regulatory definition of "greenhouse gases," to exclude biogenic CO_2 emissions based on the conclusion that biogenic CO_2 emissions do not increase net atmospheric CO_2 concentrations. EPA could also amend its Endangerment Finding to explicitly exclude biogenic CO_2 emissions based on the conclusion that simultaneous carbon sequestration in working forests mitigates any climate impacts associated with biogenic CO_2 emissions[10] In fact, in his concurring opinion in

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[10] Alternatively, EPA's determination that motor vehicle emissions contribute to endangerment of public health and welfare could be interpreted to exclude biogenic CO_2 emissions. The Endangerment Finding was based primarily on the IPCC Fourth Assessment Report of 2007 and EPA's annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, both of which exclude biogenic CO_2 emissions from Energy Sector emissions expressly on the basis of their carbon neutrality. 75 Fed. Reg. at 66,510; 66,537; *see also supra* n.3. Thus, EPA never explicitly considered

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CBD v. EPA, discussed *infra*, Judge Kavanaugh suggested that EPA could presumably exclude biogenic CO_2 emissions by 'tinker[ing] with the Endangerment Finding." *CBD*, 722 F.3d at 413 n.1 (Kavanaugh, J. concurring).

C.   Distinguishing Among GHGs Based on Global Warming Potential

In the Tailoring Rule, EPA based PSD applicability for GHG emissions on an artificial, calculated emission rate—carbon dioxide equivalents ("CO_2e")—that takes into account the different global warming potential ("GWP") of different components of the regulated pollutant "greenhouse gases." *See* 40 C.F.R. §§ 52.21(b)(49)(ii)-(v); 75 Fed. Reg. at 31,522. Thus, under current PSD regulations a new source could emit 25 times more CO_2 without obtaining a PSD permit than it could methane. *See* 40 C.F.R. §§ 52.21(b)(49)(ii) and 40 C.F.R. pt. 98 subpt. A Table A-1. This deviation from a literal application of the statutory PSD provisions is not based on EPA's GHG regulations for light-duty vehicles, since those rules set separate emission standards for CO_2, methane, and nitrous oxide, and do not involve aggregating emissions of the three compounds or applying weighting factors. *See* 75 Fed. Reg. at 25,421. Rather, EPA implemented the GWP weighting factors specifically for stationary sources in order to determine whether a new or modified source will require a PSD permit in recognition that emissions of the same annual quantity of different "greenhouse gases" can have very different potential impacts on climate change.[11] *See* 75 Fed. Reg. at 31,531 (using CO_2e, which incorporates global warming potential weighting factors, for determining PSD applicability "best addresses the relevant environmental endpoint"); *id.* at 31,531-32 (rejecting comment that EPA has no discretion to depart from actual annual mass emissions in determining PSD applicability).

EPA could employ similar discretion in the PSD permitting program to distinguish between the global warming potential of biogenic and fossil CO_2 emissions, given that biogenic emissions in the United States do not increase net atmospheric CO_2 *and* serve to offset the utilization of fossil fuels for combustion.[12] Thus, by applying a GWP of zero to biogenic CO_2 emissions, EPA could effectively exclude biogenic CO_2 emissions from regulation under the PSD permitting program. EPA has discretion to recognize the readily apparent benefits of substituting a carbon neutral fuel for one that releases carbon which may have been stored, and would otherwise remain stored, for millions of years. Such discretion is further supported by past practice; EPA has long differentiated biogenic emissions from fossil fuel emissions in its Inventory of U.S. Greenhouse Gas Emissions and Sinks and in other regulations. *See* 40 C.F.R.

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whether biogenic CO_2 emissions contribute to that endangerment in light of their role in the carbon cycle. As a result, EPA could now reasonably conclude that biogenic CO_2 is not among the air pollutants covered by its endangerment determination.

[11] EPA's use of CO_2e and GWP is consistent with EPA's practice under the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks* and with international practice under the Intergovernmental Panel on Climate Change.

[12] EPA has described the "air pollutant" that it is seeking to regulate as the flow of GHGs that changes the total, cumulative stock of greenhouse gases in the atmosphere. 74 Fed. Reg. at 66,536. It would therefore be appropriate for EPA to recognize in the PSD regulations that biogenic CO_2 emissions, which return to the atmosphere CO_2 that was recently removed from the atmosphere in the production of the biomass fuel, and that will be removed again through photosynthesis to replace that biomass, do not add to the total, cumulative stock of GHGs in the atmosphere and therefore represent a net flow of zero.

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§ 98.2(b)(2) (excluding biogenic CO_2 emissions from calculation of thresholds for determining which facilities are required to report GHG emissions). [13] Alternatively, even if EPA concluded that a complete exclusion for biogenic CO_2 emissions was unwarranted, it could apply a smaller GWP to biogenic CO_2 emissions to distinguish between the climate impacts of biogenic and fossil CO_2 emissions in the PSD and Title V permitting programs. [14]

D.   Applying Sector-Based Emissions Thresholds Under The Tailoring Rule

In the Tailoring Rule, EPA relied on three administrative law doctrines—absurd results, administrative necessity, and one-step-at-a-time—to adjust the PSD and Title V emissions thresholds for GHGs. EPA reasoned that applying PSD and Title V permitting requirements at the relatively low statutory levels intended for criteria pollutants would, in the context of GHGs, place excessive burdens on small sources and on the state and local permitting authorities that implement these permitting programs. *See, e.g.*, 75 Fed. Reg. at 31,517. Instead, EPA adopted a phased-in approach that would begin by regulating the largest emitting sources and potentially adjust the permitting thresholds downward as state and local permitting authorities gained the experience and capacity to process larger quantities of permits. By focusing the phased-in permitting program on the largest sources, EPA explained that it would "direct limited administrative resources to those new sources with the greatest impact on GHG emissions." *Id.* at 31,529; *see also id.* at 31,531 (addressing "sources and modifications that have the greatest impact on radiative forcing of the GHGs emitted").

Although EPA did not consider making adjustments in the Tailoring Rule based on the source of the emissions, *id.* at 31,591, it suggested that it would consider source-based adjustments in future rulemakings that would occur under the Tailoring Rule's phased-in approach. *See, e.g., id.* at 31,516, 31,524, 31,525, 31,590-91. In a future rulemaking under the Tailoring Rule, EPA could justify source-specific regulations for biomass combustion facilities based on the conclusion that biogenic CO_2 emissions are part of the natural carbon cycle and, therefore, are different than fossil fuel emissions. In fact, EPA specifically addressed this possibility in the Tailoring Rule:

> [T]he decision not to provide this type of an exclusion [for biogenic emissions] at this time does not foreclose EPA's ability to either (1) provide this type of an exclusion at a later time when we have additional information about an overwhelming permitting burdens due to biomass sources, or (2) provide another type of exclusion or other treatment based on some other rationale. Although we do not take a final position here, we believe that some commenters' observations about a different treatment for biomass combustion warrants further exploration as a possible rationale.

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[13] *See also*, NAFO's submission on EPA's Call for Information at 3-4; EPA, DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012 (Feb. 21, 2014).

[14] Applying a smaller GWP for biogenic CO_2 emissions from forest stocks may also be warranted if, at some future time, carbon stocks are no longer stable or increasing and EPA seeks to account for the incremental effect of the partial, rather than complete, offsetting of biogenic CO_2 emissions through sequestration.

Id. at 3,1591. In the event that EPA finds that biogenic CO_2 emissions have a negligible (or even positive) effect on atmospheric CO_2 concentrations, a permanent exclusion may be justified under one or more of the administrative law doctrines that EPA relied upon in issuing the Tailoring Rule. Alternatively, even if EPA determines that a full exclusion is not warranted at this time, it could institute even higher emissions thresholds for biogenic CO_2 emissions in recognition that the combustion of biomass for energy reduces GHG emissions when compared to fossil fuel combustion. Based on such a finding, EPA would be justified in concluding that administrative resources could be better spent by focusing on other sectors where emissions have a greater net effect on radiative forcing. EPA could also conclude that applying the same permitting thresholds to biogenic CO_2 emissions as to emissions of CO_2 from fossil fuels would produce absurd results because it would discourage construction of new sources using biomass fuel or modification of existing sources to burn biomass fuel, despite the fact that burning fossil fuel accumulates more CO_2 to the global atmosphere.[15]

III. The D.C. Circuit Decision in *CBD v. EPA* Does Not Limit EPA's Discretion to Exclude Biogenic CO_2 Emissions from PSD and Title V Permitting Requirements.

In July 2011, in response to the National Alliance of Forest Owners' petition for administrative reconsideration, EPA temporarily deferred the applicability of PSD and Title V permitting requirements to biogenic CO_2 emissions so that the Agency could study the climate impact of biogenic CO_2 emissions and determine how such emissions should be permanently treated under the PSD and Title V permitting programs. 76 Fed. Reg. 43,490 (July 20, 2011). In the so-called "Deferral Rule," EPA invoked the same administrative law doctrines as it did in the Tailoring Rule. *Id.* at 43,496-99. Center for Biological Diversity and other petitioners sought review of the Deferral Rule.

In *CBD*, the D.C. Circuit issued a decision, split three ways, vacating the Deferral Rule. 722 F.3d 401 (D.C. Cir. 2013). The majority's holding was based on the conclusion that the Deferral Rule's invocation of various administrative law doctrines was not adequately supported by the rulemaking record. *Id.* at 410 (EPA "failed to explain" why the one-step-at-a-time doctrine applied); *id.* at 411 (EPA "should have explained why it rejected" a potentially less restrictive alternative under the administrative necessity doctrine); *id* at 412 (finding EPA's reliance on the absurd results doctrine to be "post hoc"). Significantly, however, none of the three opinions suggested that EPA lacked authority to permanently exclude biogenic CO_2 emissions from the PSD and Title V permitting programs. Two of the opinions suggested that EPA retained the broad authority described above to permanently exclude biogenic CO_2 emissions, provided the Agency justified its decision in the rulemaking record. *Id.* ("leav[ing] for another day the question whether the agency has authority under the Clean Air Act to permanently exempt biogenic carbon dioxide sources from the PSD permitting program"); *id.* at 420 (Henderson, J. dissenting) (recognizing the "availability of a *de minimis* exception" to

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[15] Because fossil fuels typically have higher heat value than biomass fuels, conversion from fossil fuel to biomass usually would result in an increase in the mass of CO_2 emissions, despite the fact that it would reduce the accumulation of CO_2 in the atmosphere. Also, because the equipment to burn biomass fuels often is more costly than for fossil fuels, and the pollution control costs for non-GHG pollutants may be comparable or greater, applying the same permitting requirements to both types of fuels reduces the incentive for sources to choose the biomass fuel route.

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permanently exclude biogenic CO_2 emissions from PSD and Title V). Even the concurring opinion, which asserted that EPA's regulatory discretion was limited by the Agency's prior interpretation of its CAA authority, suggested that EPA retained some limited options to permanently exclude biogenic CO_2 emissions. *Id.* at 413 n.1 (Kavanaugh, J., concurring) (suggesting that EPA could exclude biogenic CO_2 emissions by amending its Endangerment Finding). Thus, while the Deferral Rule litigation highlighted the importance of providing a compelling legal and factual basis for excluding biogenic CO_2 emissions from regulation, nothing in the decision suggested that EPA was foreclosed from seeking permanent exclusion at the conclusion of its reconsideration process.

IV. Summary of the Factual Bases for Differentiating Biogenic CO_2 Emissions from Other GHG Emissions in CAA Permitting

While EPA has clear legal authority to exclude biogenic CO_2 emissions from the PSD and Title V permitting programs, there is also an extensive technical and factual record supporting a decision to differentiate biogenic CO_2 emissions from fossil fuel GHG emissions. This Section demonstrates that there is ample scientific support in the existing record before the Agency to support a regulation both excluding biogenic CO_2 emissions from the PSD and Title V permitting programs and supporting a distinction between biomass and other fuels. First and foremost, there is scientific consensus that, because it is part of the natural carbon cycle, biogenic carbon is fundamentally different than fossil carbon. Thus, when forests are managed sustainably, biogenic CO_2 emissions are balanced by carbon sequestered during regrowth. Relying on this scientific premise, studies repeatedly show that combusting biomass for energy offers substantial GHG mitigation benefits when compared to fossil fuel alternatives. Second, there is strong evidence that forests are currently being managed sustainably and will be for the foreseeable future. Thus, when forest carbon stocks are evaluated over appropriate time and spatial scales, there is ample support for the proposition that forests are capable of meeting increased demand without reducing overall forest carbon stocks. This section and annotated bibliography will address in turn the key principles needed to support an exclusion for biogenic CO_2 emissions based on the record that is presently before EPA.[16]

A. Because they are part of the forest carbon cycle, CO_2 emissions from the combustion of biomass are offset by carbon sequestration during regrowth.

It is well-established that all wood products—including biomass combusted for energy— are part of the natural forest carbon cycle. CO_2 is sequestered in forests through photosynthesis and emitted through decomposition and combustion. Thus, as long as forests are managed sustainably and forest carbon stocks remain stable (or increase) over time, biomass energy and other parts of the forest products sector do not increase net atmospheric GHG concentrations. In

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[16] The articles and studies cited in this section comprise only a portion of the literature that supports differential treatment of biomass emissions. The vast majority of the material presented here has already been submitted to EPA and/or the EPA Science Advisory Board in prior comments and thus is already part of the administrative record. NAFO has included a few more recent articles that provide further support for differential treatment for biomass emissions. Further, virtually all of these articles and studies are either published in peer-reviewed journals or are publicly available and accessible by EPA. NAFO is willing to provide EPA with copies of any materials cited here that are not readily available to the Agency for review.

contrast, CO_2 emissions from fossil fuel combustion permanently increase atmospheric GHG concentrations because they release carbon that has been geologically stored for millennia. Active, sustainable management of forested lands provide a number of distinct climate change mitigation benefits which serve to reduce net GHG emissions over time: (1) durable forest products such as lumber used in construction continue to store carbon for decades after harvest, (2) manufacturing forest products is much less carbon intensive than alternative products such as concrete or steel, and (3) biomass used for energy can directly displace fossil fuel emissions over multiple harvest cycles. These scientific principles have been affirmed by the Science Advisory Board and many other qualified experts:

- Science Advisory Board, *Review of EPA's Accounting Framework for Biogenic CO2 Emissions from Stationary Sources* at 7, EPA-SAB-12-011 (Sept. 22, 2012) (concluding that "[t]here are circumstances under which biomass is grown, harvested, and combusted in a carbon neutral fashion").

- Lippke, B., *et al.*, Letter from 113 Scientists to Sen. Boxer and Rep. Waxman (July 20, 2010) (explaining that biomass combustion does not increase net atmospheric CO_2 concentrations because "carbon dioxide released from the combustion or decay of woody biomass is part of the global cycle of biogenic carbon").

- Martin, R.M., *Deforestation, land-use change and REDD*, Unasylva 59(230): 3-11 (2008) ("If the land is encouraged or allowed to regenerate a new forest, the ecosystem effect of harvesting is carbon neutral. . . . The atmospheric effect becomes problematic if the cycle is broken and the land is converted to another use.").

- Lippke, B., *et al.*, CORRIM, *Life-cycle Environmental Performance of Renewable Building Materials*, Forest Prod. J., 54: 8 (2004) (highlighting climate benefits of using wood products as substitutes for other materials that have larger carbon footprints).

- Miner, R., NCASI, *Biomass Carbon Neutrality* (Apr. 15, 2010), *available at* http://www.nafoalliance.org/wp-content/uploads/NCASI-Biomass-carbon-neutrality.pdf) (explaining that biomass is carbon neutral due to its role in the carbon cycle and that additional climate benefits occur over each management cycle as additional carbon sequestration occurs through regrowth).

- Lattimore, B. *et al., Environmental Factors in woodfuel production: Opportunities, risks, and criteria and indicators for sustainable practices and utilization*, Biomass and Energy, 33: 1321-42 (2009) (explaining that biomass energy from sustainably managed forests is carbon neutral).

- Cherubini, F., *GHG balances of bioenergy systems – Overview of key steps in the production chain and methodological concerns*, Renewable Energy 35: 1565-73 (2010) ("When biomass is combusted, the resulting CO_2 is not counted for a GHG because C has a biological origin and combustion of biomass releases almost the same amount of CO_2 as was captured by the plant during its growth.").

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- Gower, S., *Patterns and mechanisms of the forest carbon cycle,* Annual Review of Environment and Resources 28: 169-204 (2003) ("The CO_2 emitted when wood and paper waste is burned is equivalent to the atmospheric CO_2 that was sequestered by the tree during growth and transformed into organic carbon compounds; hence there is no net contribution to the atmospheric CO_2 concentration; and the material is considered C neutral.").

- Sedjo, R.A., *Biomass: Short-Term Drawbacks, But Long-Term Climate Benefits*, The Energy Daily (Sept. 20, 2010) (concluding that unlike fossil fuel emissions, biogenic CO_2 emissions have no net impact on atmospheric GHG concentrations).

- Bowyer, J., *et al., Life Cycle Impacts of Forest Management and Bioenergy Production* 1-13 (July 2011), *available at* http://www.dovetailinc.org/files/DovetailLCABioenergy0711.pdf (finding that sustainably managed forest are better than carbon neutral when regeneration, displacement of fossil fuels, and long-term carbon storage in durable forest products is considered)

- Sedjo, R, *Carbon Neutrality and Bioenergy: A Zero-Sum Game?*, Resources for the Future Discussion Paper 1-9 (Apr. 2011), *available at* http://www.rff.org/documents/RFF-DP-11-15.pdf (concluding that there are no net CO_2 emissions from biomass energy as long as forest carbon stocks are stable or increasing because CO_2 emissions will be offset entirely by carbon sequestration).

- Lippke, B., *et al., Life cycle impacts of forest management & wood utilization on carbon mitigation: knowns and unknowns*, Carbon Management 2(3): 303-33 (2011) (concluding that combustion of biomass for energy produces no net CO_2 emissions as long as forest carbon stocks are stable or increasing).

- Malmshimer, R.W., *et al., Managing Forests Because Carbon Matters: Integrating Energy, Products, and Land Management Policy*, Journal of Forestry 109(7S) (2011) (concluding that there will be no net CO_2 emissions from biomass energy as long as forest carbon stocks are stable or increasing because emissions will be offset entirely by carbon sequestration).

- Fargione, J., *et al., Land clearing and the biofuel carbon debt*, Science 319: 1235-38 (2008) ("[B]iofuels made from waste biomass or from biomass grown on degraded and abandoned agricultural lands planted with perennials incur little or no carbon debt and can offer immediate and sustained GHG advantages.").

- Lippke, B. and E. Oneil, CORRIM, *Unintended Consequences of the Proposed EPA Tailoring Rule Treatment of Biomass Emissions the Same as Fossil Fuel Emissions* (2010) ("Life cycle research results accumulated over the last decade . . . demonstrate that the emissions from burning biomass for energy are being offset by the sustained growth in forest carbon.").

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B.   Scientific studies have repeatedly shown that biomass combustion for energy results in significant GHG emissions reductions when compared to fossil fuel alternatives.

Over the past 20 years scientific studies evaluating biomass energy have consistently found significantly lower net GHG emissions when compared to fossil fuel combustion. In particular, a number of recent studies focused directly on the question of carbon neutrality have determined that there are no net CO_2 emissions from woody biomass as long as forests are managed sustainably. Other studies—including a number of life cycle analyses—have attempted to quantify in absolute terms the GHG mitigation benefit of substituting biomass energy for fossil fuels. These studies also identify substantial reductions in GHG emissions, but do not directly answer the question whether biomass combustion for energy results in any net CO_2 emissions. However, these studies consistently conclude that active forest management focused on supplying forests products and biomass energy produces the greatest GHG mitigation benefits from forested lands. While many life cycle analyses show small net GHG emissions from biomass energy, they include certain emissions sources, such as those associated with the harvest and transport of biomass feedstocks, that should be excluded when considering net CO_2 emissions for purposes of PSD and Title V permitting under the Clean Air Act. *See* Science Advisory Board, *Review of EPA's Accounting Framework for Biogenic CO2 Emissions from Stationary Sources* at 7, EPA-SAB-12-011 (Sept. 22, 2012) ("While EPA's primary goal is to account for this offsetting sequestration, its biogenic emission accounting should be consistent with emissions accounting for fossil fuels for other emissions accounting categories—including losses, international leakage, and fossil fuel use during feedstock extraction, production and transport. Including some emissions accounting elements for biomass and not for fossil fuels would be a policy decision without the underling science to support it.").

- Schlamadinger, B., *et al., Towards a standard methodology for greenhouse gas balances of bioenergy systems in comparison with fossil energy systems*, Biomass and Bioenergy 13(6): 359-75 (1997) (finding that biomass-based fuels produce climate benefits when compared to fossil fuels).

- Abbasi, T. and S. Abbasi, *Biomass energy and the environmental impacts associated with its production and utilization*, Renewable and Sustainable Energy Reviews 14: 919-37 (2010) (finding that biomass-based fuels produce climate benefits when compared to fossil fuels).

- Froese, R.E., *et al., An evaluation of greenhouse gas mitigation options for coal-fired power plants in the U.S. Great Lakes States*, Biomass and Bioenergy 34: 251-62 (2010) (finding that, in the Great Lakes region, co-firing 20% forest residuals in coal-fired power plant reduced GHG emissions by 20%).

- DOE, Ethanol Benefits, *available at* http://www.afdc.energy.gov/afdc/ethanol/benefits.html ("Cellulosic ethanol would reduce GHGs by as much as 86%.").

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- EPA, Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, Final Rule, 75 Fed. Reg. 14,670 (Mar. 26, 2010) (finding that cellulosic ethanol reduces lifecycle GHG emissions by more than 60% when compared to conventional fuels).

- EPA, *Renewable Fuel Standard Program, Draft Regulatory Impact Analysis* at 191 (Sept. 2006), EPA420-D-06-008 (finding that cellulosic ethanol reduces lifecycle GHG emissions by 92.7% when compared to conventional fuels).

- Mann, M.K. and P.L. Spath, *A life cycle assessment of biomass cofiring in a coal-fired power plant*, Clean Production Processes 3: 81-91 (2001) (finding that cofiring 15% wood residuals in coal-fired power plant reduced GHG emissions by 18.4%).

- Robinson, A.L., *et al.*, *Assessment of potential carbon dioxide reductions due to biomass – Coal cofiring in the United States*, Environmental Science and Technology 37(22): 5081-89 (2003) (concluding that cofiring forestry and agricultural residuals with coal reduce CO2 emissions by as much as 95% when compared to fossil fuel combustion).

- Pehnt, M, *Dynamic life cycle assessment (LCA) of renewable energy technologies*, Renewable Energy 31: 55-71 (2006) (finding that combustion of biomass feedstocks such as forest wood, short rotation forestry wood, and waste wood for energy could reduce life cycle GHG emissions by between 85 and 95% when compared to fossil fuels).

- Cherubini, F., *et al.*, *Energy- and greenhouse gas-based LCA of biofuel and bioenergy systems: Key issues, ranges and recommendations,* Resources, Conservation, and Recycling 53: 434-47 (2009) (finding that combustion of forestry residuals for energy reduce life cycle GHG reductions by between 90 and 95%).

- Zhang, Y., *et al.*, *Life cycle emissions and cost of producing electricity from coal, natural gas, and wood pellets in Ontario Canada*, Environmental Science and Technology 44(1): 538-44 (2010) (finding that combustion of wood harvest specifically for energy production reduced lifecycle GHG emissions by 91% relative to coal and by 78% relative to natural gas).

- Raymer, A.K.P., *A comparison of avoided greenhouse gas emissions when using different kinds of wood energy*, Biomass and Bioenergy 30: 605-17 (2006) (concluding that combustion of biomass feedstocks such as fuel wood, sawdust, wood pellets, demolition wood, briquettes, and bark for energy production reduced lifecycle GHG emissions by between 81 and 98%).

- Heller, M.C., *et al.*, *Life cycle energy and environmental benefits of generating electricity from willow biomass*, Renewable Energy 29: 1023-42 (2004) (finding that cofiring 10% willow, a short rotation woody biomass feedstock, with coal reduced GHG emissions by 9.9%).

- Heller, M.C., *et al.*, *Life cycle assessment of a willow bioenergy cropping system*, Biomass and Bioenergy 25: 147-65 (2003) (finding that cofiring 10% willow, a short rotation woody biomass feedstock, with coal reduced GHG emissions by 9.9%).

- Bowyer, J., *et al.*, Life Cycle Impacts of Forest Management and Bioenergy Production 1-13 (July 2011), *available at* http://www.dovetailinc.org/files/DovetailLCABioenergy0711.pdf (finding that on a life cycle basis, biomass energy reduces GHG emissions by 96% in comparison to coal).

- Gaudreault, C., *et al.*, *Life cycle greenhouse gases and non-renewable energy benefits of kraft black liquor recovery*, Biomass and Bioenergy 46: 683-92 (2012) (finding that combustion of black liquor from Kraft pulping operations for energy reduced lifecycle GHG emissions by 90% relative to coal).

- Hall, D.O., *et al.*, *Alternative roles for biomass in coping with greenhouse gas warming*, Science & Global Security 2: 113-51 (1991) (finding that combustion of woody biomass for energy produces substantial GHG benefits over time when used as a substitute for coal).

- Marland, G. and B. Schlamadinger, *Forests for carbon sequestration or fossil fuel substitution: A sensitivity analysis*, Biomass and Bioenergy 13: 389-97 (1997) (concluding that the use of woody biomass as a substitute for coal in energy production yields substantial GHG emissions reductions over time).

- Schlamadinger, B. and G. Marland, *The role of forest and bioenergy strategies in the global carbon* cycle, Biomass and Bioenergy 13: 275-300 (1996) (concluding that the use of woody biomass as a substitute for coal in energy production yields substantial GHG emissions reductions over time).

- Abt, R.C. *et al.*, Climate Change Policy Partnership, Duke University, *The near-term market and greenhouse gas implications for forest biomass utilization in the Southeastern United States* (2010) (concluding, in a study of forests in the southeastern United States, that the harvest and combustion of biomass for energy "generat[es] net GHG reductions relative to the baseline" when used as a substitute for coal).

- Zanchi, G., *et al.*, *Is woody bioenergy carbon neutral? A comparative assessment of the emissions from consumption of woody bioenergy and fossil fuel*, GCB Bioenergy 4: 761-72 (2012) (finding that combustion of biomass for energy produces long-term reductions in cumulative GHG emissions when compared to combustion of fossil fuels)

- Nabuurs, G.J., *et al.*, *Forestry*, Chapter 9 in Climate change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, (B. Metz, *et al.*, eds.) (2007) ("In the long-term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit.")

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- Ryan, M.G., *et al.*, *A synthesis of the science on forests and carbon for U.S. forests*, Issues in Ecology 13: 1-16 (2010) ("[T]he maximum potential benefit from a project that reestablished forest increases if the stand is periodically harvested and the wood is used for substitution and the biomass used for fuel.")

- Gaudreault, C. and R. Miner, *Greenhouse Gas and Fossil Fuel Reduction Benefits of Using Biomass Manufacturing Residues for Energy Production in Forest Products Manufacturing Facilities*, Technical Bulleting No. 1016, National Council for Air and Stream Improvement (2013) (finding that combustion of mill residuals for energy reduces lifecycle GHG emissions by 86 to 99% when compared to fossil fuels)

- Electric Power Research Institute, *Biopower Generation: Biomass Issues, Fuels, Technologies, and Opportunities for Research, Development, and Deployment* (Feb. 24, 2010), *available at* http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001020784 ("Direct firing of biomass is the only proven carbon-neutral generation technology that is both suitable for baseload operation and available for immediate deployment to support capacity expansion.").

- Interlaboratory Working Group, Oak Ridge, TN and Berkeley, CA: Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory, *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond*, ORNL-444 and LBNL-40533 (1997) (concluding that cofiring biomass with fossil fuels was the single largest potential contributor to near-term GHG emissions reduction of any renewable energy strategy).

- Matthews, R. and K. Robertson, EIA Bioenergy Task 38, *Answers to Ten Frequently Asked Questions about Bioenergy, Carbon Sinks and Their Role in Global Climate Change* (2nd ed. 2005), *available at* www.ieabioenergy-task38.org/publications/faq/ (finding that between 25 and 50 units of bioenergy are produced for every unit of fossil fuel energy consumed in production) (citing Börjesson (1996), Boman and Turnbull (1997), McLaughlin and Walsh (1998), Matthews (2001). and Elsayed *et al.* (2003)).

- Jones, G., *et al.*, *Forest treatment residues for thermal energy compared with disposal by onsite burning: Emissions and energy return*, Biomass and Bioenergy 34: 737-46 (2010) (finding that, for forest residues in western Montana, an average of 21 units of bioenergy are produced for every unit of fossil fuel energy consumed in production).

- Walker, T., *et al.*, Manomet Center for Conservation Sciences, *Biomass Sustainability and Carbon Policy Study* (2010) ("All bioenergy technologies, even biomass electric power compared to natural gas electricity, look favorable when biomass waste wood is compared to fossil fuel alternatives.").

- Heath, L., *et al.*, *Greenhouse gas and carbon profile of the U.S. forest products industry value chain*, Environmental Science and Technology 44: 3999-4005 (2010) (explaining that active forest management that produces forest products and biomass energy reduces overall atmospheric GHG concentrations).

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- Morris, G., Pacific Institute, *Bioenergy and Greenhouse Gases* (May 15, 2008), *available at* http://www.pacinst.org/reports/Bioenergy_and_Greenhouse_Gases/Bioenergy_and_Greenhouse_Gases.pdf (finding that the California biomass energy industry produces significant GHG emission reduction benefits by displacing fossil CO_2 emissions from energy production and by avoiding GHG emissions otherwise associated with alternative disposal options for biomass).

- Werner, F., *et al.*, *National and global greenhouse gas dynamics of different forest management and wood use scenarios: A model based assessment*, Environmental Science and Policy 13: 72-85 (2010) (finding that the contributions of the forestry and timber sector to mitigate climate change can be optimized when sustainable harvests are maximized and harvested wood is processed in accordance with the principles of cascade use including the use of "waste wood" residues to generate energy).

    C.   Net CO_2 emissions from biomass energy must be evaluated over broad spatial and time scales.

Accounting for net CO_2 emissions from biomass energy is scale-dependent, and much of the controversy surrounding biogenic CO_2 emissions has arisen from studies relying on inappropriate spatial and time scales. This is particularly true for forest-based biomass, which is managed on longer rotation cycles. With respect to spatial scales, studies repeatedly demonstrate that a broad, landscape-based approach is necessary to account for the harvest and regrowth that happen simultaneously in different stands over time. Moreover, such an approach is consistent with the spatial scales over which working forests are managed. Likewise, accounting for net CO_2 emissions from biomass requires a long time scale that captures the longer rotation lengths over which forests are managed. A longer time scale is also consistent with climate science because cumulative net emissions, not near-term annual emissions, will determine peak warming.

- O'Laughlin, J., University of Idaho, College of Natural Resources Policy Analysis Group Report No. 31, *Accounting for Greenhouse Gas Emissions from Wood Bioenergy* (Sept. 13, 2010), *available at* http://www.uidaho.edu/~/media/Files/orgs/CNR/PAG/Reports/PAGReport31 (explaining why a landscape-based approach to carbon accounting is required to reflect that emission and sequestration occur simultaneously, while a stand-based accounting approach misses this point).

- Malmshimer, R.W., *et al.*, *Managing Forests Because Carbon Matters: Integrating Energy, Products, and Land Management Policy*, Journal of Forestry 109(7S) (2011) (explaining that bioenergy offers long-term GHG reduction benefits compared to continued sequestration because forest carbon stocks will eventually reach equilibrium, while bioenergy production continually displaces fossil fuel emissions).

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- Lippke, B., *et al., Life cycle impacts of forest management & wood utilization on carbon mitigation: knowns and unknowns*, Carbon Management 2(3): 303-33 (2011) (explaining that bioenergy offers long-term GHG reduction benefits compared to continued sequestration because forest carbon stocks will eventually reach equilibrium, while bioenergy production continually displaces fossil fuel emissions).

- Sedjo, R, *Carbon Neutrality and Bioenergy: A Zero-Sum Game?*, Resources for the Future Discussion Paper 1-9 (Apr. 2011), *available at* http://www.rff.org/documents/RFF-DP-11-15.pdf (explaining that a broad, landscape-based spatial scale for carbon accounting is necessary to appropriately reflect the simultaneous regrowth and harvest that take place on individual stands of forested land).

- Strauss, W., *How Manomet got it backwards: Challenging the "debt-then-dividend" axiom* (May 2011), *available at* http://www.futuremetrics.net/papers/Manomet%20Got%20it%20Backwards.pdf (explaining that a broad, landscape-based spatial scale for carbon accounting is necessary to appropriately reflect the simultaneous regrowth and harvest that take place on individual stands of forested land).

- Bowyer, J., *et al.*, Dovetail Partners, *Carbon 101: Understanding the Carbon Cycle and the Forest Carbon Debate* (Jan. 2012), *available at* http://www.dovetailinc.org/files/DovetailCarbon101Jan2012.pdf (explaining that a broad landscape-based spatial scale demonstrates that overall forest carbon stocks remain stable when harvests take place at different times on different forest stands).

- Lucier, A., National Council for Air and Stream Improvement, Inc., *NCASI Review of Manomet Biomass Study*, (2010), *available at* http://www.mass.gov/Eoeea/docs/doer/renewables/biomass/study-comments/lucier.pdf (explaining that stand-based carbon accounting approaches fail to reflect the simultaneous harvest and regrowth that occurs across a sustainably-managed forested landscape).

- Galik, C.S. and R.C. Abt, *The Effect of Assessment Scale and Metric Selection on the Greenhouse Gas Benefits of Woody Biomass*, Biomass & Bioenergy, 44: 1-7 (2012) (concluding that "state, procurement area, and landowner assessment scales most closely approximate the actual GHG emission implications" of biomass energy).

- Meinshausen, M., *et al., Greenhouse-gas emission targets for limiting global warming to 2°C*, Nature 248: 1158-62 (2009) (concluding that a long time frame is appropriate to assess climate impacts of alternative GHG emission scenarios because cumulative net emissions, rather than near-term annual emissions, will determine peak warming).

- Allen, M., *et al., Warming caused by cumulative carbon emissions: Toward the trillionth ton*, Nature 458: 1163-66 (2009) (concluding that a long time frame is appropriate to assess climate impacts of alternative GHG emission scenarios because cumulative net emissions, rather than near-term annual emissions, will determine peak warming).

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- Helin, T., *et al.*, *Approaches for inclusion of forest carbon cycle in life cycle assessment – a review*, GCB Bioenergy 5: 475-86 (2013) (concluding that the climate effects of biogenic CO_2 emissions are best characterized by analyzing cumulative radiative forcing over 100-year period).

- Ryan, M.G., *et al.*, *A synthesis of the science on forests and carbon for U.S. forests*, Issues in Ecology 13: 1-16 (2010) (explaining that GHGs are global pollutants with centuries-long effective lifespans and, therefore, must be analyzed over long periods of time and large areas).

- Nechodom, M., U.S. Department of Agriculture, U.S. Forest Service, Pacific Southwest Research Station, *Biomass to Energy: Forest Management for Wildlife Reduction, Energy Production, And Other Benefits*, CEC-500-2009-080 (modeling forest vegetation growth over 40-year period in assessment of biomass energy).

- Miner, R., National Council for Air and Stream Improvement, Inc.*, Biomass Carbon Neutrality* (Apr. 15, 2010)*, available at* http://www.nafoalliance.org/wp-content/uploads/NCASI-Biomass-carbon-neutrality.pdf) (explaining that a landscape-based approach is necessary for carbon accounting because the emissions from harvesting certain forest stands are offset by the sequestration of carbon through new growth in other stands that will be harvested in the future).

- Lippke, B. & E. Oneil, CORRIM, *Unintended Consequences of the Proposed EPA Tailoring Rule Treatment of Biomass Emissions the Same as Fossil Fuel Emissions* (2010), *available at* http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.189.3736&rep=rep1&type=pdf (explaining that when forests are managed sustainably, carbon neutrality is observed at the stand level over multiple rotations, and at the landscape level at any given point in time).

D.   Forest carbon stocks are stable or increasing across the United States.

Stability in forest carbon stocks is an essential prerequisite for establishing that biogenic CO_2 emissions do not increase net atmospheric CO_2 concentrations. If forests are converted to other land uses after harvest, the forest carbon cycle is broken. Thus, while some stand-based changes are inevitable, given urban development and other external pressures, it is essential to ensure that, at a broader landscape level, forest carbon stocks are not depleted as a result of biomass energy. Whether viewed nationally, or on a regional basis, studies consistently find that forest carbon stocks have remained stable—and in many cases increased significantly—over the past 60 years, and this stability has occurred despite significant increases in demand for forest products. Further, projections by the U.S. Forest Service and others suggest that this stability will continue for decades to come.

- Field, C.B., *Primary production for the biosphere: integrating terrestrial and oceanic components*, Science 281: 237-40 (1998) (finding that forests sequester 25-30 billion metric tons of carbon per year).

- Sabine, C.L., *et al., Current status and past trends of the carbon cycle, in* The global carbon cycle: integrating humans, climate, and the natural world 17-44 (C.B. Field & M.R. Raupach, eds. 2004) (finding that U.S. forests are a carbon sink).

- Society of American Foresters, *The State of America's Forests* (2007), *available at* http://www.safnet.org/publications/americanforests/StateOfAmericasForests.pdf (noting a 50% increase in forest carbon stocks over second half of the 20th century).

- U.S. Climate Change Science Program and the Subcommittee on Global Change Research, NOAA, *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle* (King, A.W., *et al.*, eds., 2007) (finding that forests are the largest carbon sink in North America).

- EPA, 2009 US Inventory of Greenhouse Gas Emissions and Sinks: 1990-2007 (stating that U.S. forests capture 10-15% of annual GHG emissions).

- Haynes, R.W., USDA Forest Service, Pacific Northwest Research Station, *The 2005 RPA timber assessment update*, Gen. Tech. Rep. PNW-GTR-699 (2007) (finding that private forests are a net carbon sink and sequester 131 metric tons of CO_2 per year).

- Heath, L.V., *Greenhouse Gas and Carbon Profile of the U.S. Forest Products Industry Value Chain*, Environmental Science and Technology (2010) (projecting that private forests will continue to be a net carbon sink through at least 2040).

- EPA, 2010 US Inventory of Greenhouse Gas Emissions and Sinks: 1990-2008 ("[I]mproved forest management practices, the regeneration of previously cleared lands, and timber harvesting and use have resulted in net uptake (i.e. net sequestration) of [carbon] each year from 1990 through 2008.").

- Smith, W., *et al.., U.S. Department of Agriculture, U.S. Forest Service, Forest Resources of the United States 2007 – General Technical Report WO-78* (2007) (concluding, based on data from 1980 to 2007, that forest carbon stocks are stable or increasing in the Rocky Mountain, Pacific Coast, South, and North regions, and for the U.S. as a whole).

- Walker, T., *et al., Manomet Center for Conservation Sciences, Biomass Sustainability and Carbon Policy Study* (2010) (finding that forest carbon stocks in New England are increasing).

- Heath, L.S., *et al., Managed Forest Carbon Estimates for the U.S. Greenhouse Gas Inventory, 1990-2008*, Journal of Forestry 109(3): 167-73 (2011) (finding that overall forest sequestration is increasing and projecting that forest carbon stocks will remain stable for the foreseeable future).

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- Pan, Y, *et al., A Large Persistent Carbon Sink in the World's Forests*, Science 333(6054): 988-93 (Aug. 19, 2011) (reporting that United States forest carbon stocks increased by 33% from 1990 to 2007).

- Bowyer, J., *et al.,* Dovetail Partners, *Carbon 101: Understanding the Carbon Cycle and the Forest Carbon Debate* (Jan. 2012), *available at* http://www.dovetailinc.org/files/DovetailCarbon101Jan2012.pdf (noting that between 1950 and 2010 forest carbon stocks increased nationally and across the North, South, Rocky Mountain, and Pacific Northwest regions).

- *More Parkland for Massachusetts*, Northern Woodlands 21 (Summer 2012) (reporting forest carbon stocks in Massachusetts are stable).

- Ince, P.J. and P. Nepal, U.S. Department of Agriculture, U.S. Forest Service, *Effects on U.S. Timber Outlook of Recent Economic Recession, Collapse in Housing, and Wood Energy Trends*, General Technical Report FPL-GTR-219 (Dec. 2012) (projecting that domestic forest carbon stocks will grow through 2060).

- Nepal, P., *et al., Projection of U.S. forest sector carbon sequestration under U.S. and global timber market and wood energy consumption scenarios, 2010-2060*, Biomass and Bioenergy 45: 251-64 (2012) (projecting that U.S. forest carbon stocks will increase annually until at least 2045 and will have net growth from current levels until at least 2060).

- Alavalapati, J.R.R., *et al., Forest Biomass-Based Energy, in* The Southern Forest Futures Project: technical report, United States Department of Agriculture (2013) (projecting that increased demand for biomass energy will not reduce forest carbon stocks because increased harvest rates will be offset by increased productivity of fast-growing plantation species).

- Alvarez, M. *The State of America's Forests,* Society of American Foresters (2007) (finding that the amount of forested land in the United States has been essentially constant since 1900).

- Birdsey, *et al., Forest carbon management in the United States: 1600-2100*, Journal of Environmental Quality 35: 1461-69 (2006) (finding that U.S. forests and forest products have been a consistent carbon sink since at least the early 1950s).

- The Heinz Center for Science, Economics, and the Environment, *State of the Nations Ecosystem Report* (2008) ("Since 1953, the amount of carbon stored in live trees—the largest carbon pool in forests reported here—has increased by 43%.").

- Lippke, B., *et al.*, Letter from 113 Scientists to Sen. Boxer and Rep. Waxman (July 20, 2010) (explaining that forested acres have been stable for 100 years, while forest carbon stocks have increased by 50%).

- Forisk Consulting, *Woody Biomass as a Forest Product: Wood Supply and Market Implications* (Oct. 2011) (projecting an adequate supply of woody biomass to meet estimated bioenergy demands through 2022).

- Forisk Consulting, *Three Realities of Wood Bioenergy and Forest Owners* (2010), *available at* http://backup.forisk.com/UserFiles/File/Three%20Realities%20of%20Wood%20Bioenergy%20and%20Forest%20Owners%20final.pdf ("Timber per acre in the US has increased nearly one-third since 1952 and US forest growth has exceeded harvest since the 1940s.").

E.   Increased demand for biomass energy feedstocks will not deplete forest carbon stocks.

Despite the stability in forest carbon stocks over time, some have expressed concern that increased demand for biomass energy will reduce the amount of carbon that would otherwise be stored in forests. However, these concerns are inconsistent with the market factors that influence forest management decisions. Studies have repeatedly found that forest owners will respond to increased demand for biomass energy (or any other forest product) by increasing production, and thereby increasing forest carbon stocks. In the case of biomass energy, such responses can take several forms, including (1) increased consumption of existing harvest residuals, (2) increased productivity through investments in forest management practices, and (3) land use changes such as afforestation, reforestation, or avoided deforestation.

- Science Advisory Board, *Review of EPA's Accounting Framework for Biogenic CO2 Emissions from Stationary Sources* at 7, EPA-SAB-12-011 (Sept. 22, 2012) ("Some research has shown that when a future demand signal is strong enough, expectations about biomass demand for energy (and thus revenues) can reasonably be expected to produce anticipatory feedstock production changes with associated changes in land management and land use . . . .").

- Nechodom, M., U.S. Department of Agriculture, U.S. Forest Service, Pacific Southwest Research Station, *Biomass to Energy: Forest Management for Wildlife Reduction, Energy Production, And Other Benefits*, CEC-500-2009-080 (Jan. 2010) (finding that the transition from passive to active management can occur without "carbon debt" due to reduced carbon losses from wild fire).

- Zhang, J., *et al.*, U.S. Department of Agriculture, U.S. Forest Service, Pacific Southwest Research Station, *To Manage or Not to Manage: The Role of Silviculture in Sequestering Carbon in the Specter of Climate Change* RMRS-P-61 /(2010) (showing that active forest management increased carbon sequestration and decreased fire-caused mortality).

- Clutter, M., *et al., A Developing Bioenergy Market and its Implications on Forests and Forest Products Markets in the United States* (prepared for NAFO, 2010) *available at* http://www.nafoalliance.org/wp-content/uploads/NAFO-Executive-Summary-Clutter-Et-Al-Final.pdf (concluding that capacity exists to increase forest productivity by as much as 150% in South and Pacific Coast regions in response to increased market demand).

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- James, C., *et al., Carbon Sequestration in Californian Forests; Two Case Studies in Managed Watersheds* (2007) *available at* http://www.spi-ind.com/html/forests_research.cfm (concluding that implementing optimal policy incentives could double the amount of carbon sequestered by forests).

- Wear, D.N. and J.P. Prestemon, *Timber market research, private forests and policy rhetoric, in* Southern Forest Science: Past, Present, and Future General Technical Report SRS-75, Southern Research Station, USDA Forest Service, Ashville, NC (H.M. Raucher and K. Johnsen, eds. 2004) (explaining that economic return for forest products creates incentives for private forest stewardship).

- Lubowski, R.N., *et al.*, Economic Research Service, U.S. Department of Agriculture, *Environmental Effects of Agricultural Land-Use Change: The Role of Economics and Policy*, Economics Research Report No. 25, (Aug. 2006) (concluding that in the absence of market incentives, many working forests would be converted to non-forest uses).

- Ince, P.J., *Global Sustainable Timber Supply and Demand, in* Sustainable Development in the Forest Products Industry, Chapter 2, 29-41 (2010) (finding positive correlation between markets for forest products, including bioenergy, and annual increases in forest carbon stocks).

- Sedjo, R, *Carbon Neutrality and Bioenergy: A Zero-Sum Game?*, Resources for the Future Discussion Paper 1-9 (Apr. 2011), *available at* http://www.rff.org/documents/RFF-DP-11-15.pdf (explaining that bioenergy contributes to strong markets for forest products and creates incentives for forest owner to invest in forests rather than alternative land uses).

- Innovative Natural Resources Solutions LLC, *Identifying and Implementing Alternatives to Sustain the Wood-Fired Electricity Generating Industry in New Hampshire* (Jan. 2002), *available at* http://www.inrsllc.com/download/wood_firedelectricityinNH.pdf (explaining that biomass energy markets provide incremental value from low-grade forest products and help ensure that forests remain an economically competitive land use option in New Hampshire).

- Kingsley, E., *Importance of Biomass Energy Markets to Forestry: New England's Two Decades of Biomass Energy Experience* (June 2012), *available at* http://www.usendowment.org/images/Importance_of_Biomass_Energy_Markets_to_Forestry_6.2012.pdf (explaining that biomass energy markets provide incremental value from low-grade forest products and help ensure that forests remain economically competitive with other land uses).

- Maine Forest Service, *Maine Forest Service Assessment of Sustainable Biomass Availability* (July 17, 2008), *available at* http://www.maine.gov/dacf/mfs/about/state_assessment/downloads/maine_assessment_and_strategy_final.pdf (projecting that forest productivity in Maine could be increased by 88-273% through additional investments in site preparation, planting, competition control, and thinning).

- Sedjo, R. and X. Tian, *Does Wood Bioenergy Increase Carbon Stocks in Forests?*, Journal of Forestry 110: 304-11 (2012) (concluding that when "demand [for biomass] is greater than the sustainable harvest of the forest, prices will rise, total forest area will expand to meet the increasing demand, and in the process, will capture and store more carbon").

- Sedjo, R. and B. Sohngen, *Wood as a Major Feedstock for Biofuel Production in the United States: Impacts on Forests and International Trade*, Journal of Sustainable Forestry 23: 195-211 (2003) (explaining that strong market signals supporting future demand for forest products will cause forest owners to make anticipatory changes to ensure that the demand will be met).

- Wear, D.N. and J.G. Greis, *The Southern Forest Futures Project: Summary Report* (May 12, 2011), *available at* http://www.srs.fs.usda.gov/futures/reports/draft/summary_report.pdf (explaining that strong timber markets (1) encourage landowners to retain forests rather than converting them to other land uses and (2) encourage continued investment in forest management).

- MacCleery, D., *American Forests: A History of Resiliency and Recovery* (1996) (concluding that biomass energy can be an important new market that replaces other markets with declining demand and adds economic value to private forest ownership).

- Alavalapati, J.R.R., *et al.*, *Forest Biomass-Based Energy*, *in* The Southern Forest Futures Project: technical report, United States Department of Agriculture (2013) (projecting that under high biomass energy demand scenarios forest owners will increase productivity and expand the number of forested acres to meet demand).

- Daigneault, A., *et al.*, *Economic approach to assess the forest carbon implications of biomass energy*, Environmental Science and Technology 46: 5664-71 (2012) (explaining that strong markets for biomass keep land forested and encourage the planting of new forests).

- Lubowski, R., *et al.*, *What drives land-use change in the United States? A National Analysis of Landowner Decisions*, Land Economics 84: 529-50 (2008) (explaining that demand for wood produces investments by landowners that prevent forest loss through land use change an encourage afforestation).

- Hardie, I., *et al.*, *Responsiveness of rural and urban land uses to land rent determinations in the U.S. South*, Land Economics 76: 659-73 (2000) (explaining that demand for wood produces investments by landowners that prevent forest loss through land use change an encourage afforestation).

- Abt, R.C. *et al.,* Climate Change Policy Partnership, Duke University, *The near-term market and greenhouse gas implications for forest biomass utilization in the Southeastern United States* (2010) ("Forest harvest and planting decisions are affected by an uptick in demand for biomass, which in turn affects net carbon storage over time.").

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F.   Increased demand for biomass energy will not result in the harvest of high-grade mature trees for energy.

Despite its promise as a renewable energy source that does not increase atmospheric CO_2 concentrations, biomass energy relies on low-cost biomass feedstocks to remain competitive with other types of energy. Thus, biomass energy feedstocks are commonly composed of mill residues, harvest residuals, thinning treatments, and other low-grade feedstocks. In contrast, high-grade trees are reserved for saw timber and other similar products that command higher prices. Given the price differential between low-grade biomass energy feedstocks and saw timber, it is unlikely that high-grade, mature trees would ever be harvested exclusively for biomass energy production. While increased demand for biomass energy could increase prices to some degree, even the most optimistic projections for biomass energy would not raise feedstock prices to the point that landowners would begin managing forests for biomass energy instead of high-value saw timber. Thus, concerns over carbon stock depletion due to the harvest of high-grade, mature trees for biomass energy are misplaced.

- Forisk Consulting, *Woody Biomass as a Forest Product: Wood Supply and Market Implications* (Oct. 2011) (finding that a 435% increase in biomass energy demand by 2016 would be required to make forest management exclusively for biomass energy as profitable as management for saw timber).

- Ince, P.J., *Global Sustainable Timber Supply and Demand, in* Sustainable Development in the Forest Products Industry, Chapter 2 29-41 (2010) (explaining that biomass energy feedstocks are among the lowest value forest products).

- Innovative Natural Resources Solutions LLC, *Identifying and Implementing Alternatives to Sustain the Wood-Fired Electricity Generating Industry in New Hampshire* (Jan. 2002), *available at* http://www.inrsllc.com/download/wood_firedelectricityinNH.pdf (explaining that biomass energy relies on low-cost, low-grade feedstocks, not high-grade grade feedstocks that command higher prices in the market).

- Kingsley, E., *Importance of Biomass Energy Markets to Forestry: New England's Two Decades of Biomass Energy Experience* (June 2012) (explaining that biomass energy relies on low-cost, low-grade feedstocks, not high-grade feedstocks that command higher prices in the market).

- Maine Forest Service, *Maine Forest Service Assessment of Sustainable Biomass Availability* (July 17, 2008) (concluding that Maine has 9.69 million green tons per year of unutilized biomass available for biomass energy).

- U.S. Department of Energy, *Billion-ton update: biomass supply for a bioenegy and bioproducts industry* (2011) (projecting that a goal of replacing 30% of U.S. fossil fuel consumption with biomass resources can be achieved without using current pulpwood or saw timber supplies).

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Conclusion

It is clear that EPA has the legal authority, the record support, and the discretion to exclude biogenic CO_2 emissions from the CAA and/or the PSD permitting program or, in the alternative, to differentiate between biogenic CO_2 emissions and other GHG emissions. As EPA reconsiders the treatment of biogenic CO_2 emissions in the Tailoring Rule, it must reconcile the Tailoring Rule with both sound science and policy regarding renewable energy. By regulating CO_2 emissions from biomass combustion identically to fossil fuel GHG emissions, the Tailoring Rule both ignores well-settled principles regarding the balance of biogenic CO_2 emissions and CO_2 sequestration in the United States and removes any regulatory incentive to utilize biomass in place of coal and other fossil fuels.

Update and Context for U.S. Wood Bioenergy Markets

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| June 2013

Executive Summary

This paper quantifies the current baseline for forest industry wood consumption in the United States in order to provide context for wood bioenergy market developments and research. Specifically, we address the following questions:

- What is the current status of wood demand from bioenergy in the United States and how has it evolved since 2010?
- What is the current status of traditional wood demand from the forest products industry and forest supplies/growth in the U.S.?
- What are reasonable expectations for wood bioenergy growth in the U.S. relative to the forest products industry over the next ten years?

Establishing the current forest industry baseline and specifying what is "doable" and "operable" in regional U.S. bioenergy markets provides a factual basis for evaluating how wood bioenergy markets could affect forest supplies.

Key findings from this research include:

- Analysis and tracking of wood bioenergy projects by technology type and region affirm the slow, stuttered development of wood bioenergy markets in the United States. Two types of projects have led progress in wood bioenergy markets over the past three years. First, industrial combined-heat-and-power (CHP) plants and firms that build industrial CHP facilities and either use the electricity and heat/power produced for their own manufacturing plants or sell it to neighboring facilities. Second, pellet plants targeting both domestic and export markets have made progress.
- Since 2010, total potential wood use from announced and operating projects increased 3% while potential wood use from operationally "viable" projects increased approximately 10%. Based on Forisk analysis, 293 projects representing potential wood use of 75.4 million tons per year by 2023 pass basic viability screening. This estimate includes all woody feedstocks, including pulpwood, logging residues, and mill residuals.
- Consensus exists across public, private and international studies and data sources regarding the size and status of the U.S. forest products industry. Demand for "industrial" roundwood – the logs used at manufacturing facilities – is approximately 500 million tons per year during normal economic conditions.
- Wood bioenergy scenarios developed by the IPCC and applied to models of U.S. forests fail to account for the economic recession and the viable scale of actual and operable wood bioenergy projects.
- Viable wood bioenergy scenarios developed separately by U.S. Forest Service researchers and Forisk find the marginal increase in wood demand for pulpwood and logging residues from viable bioenergy projects compared to the overall forest industry in 2023 could be as much as 9% of the total wood use of the forestry sector or as little as 4%. The vast majority of wood use will still be from the traditional forest products sector. No viable scenario generates wood demand levels at the regional or national level that affect net forest growth or sustainability. While wood bioenergy projects could have no negative impact on forest supplies in the aggregate, local impacts will vary based on individual wood baskets and timber markets.

Acknowledgements: we wish to thank NCASI and researchers at the U.S. Forest Service for their willingness to share and discuss ideas and assumptions related to wood bioenergy markets and forest supply modeling associated with the RPA Assessments.

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Introduction

Wood bioenergy markets in the United States continue to perplex interested parties. In particular, questions arise regarding how developing bioenergy markets will affect the use and demand for wood and, in turn, how this demand will affect wood supplies and economics in the overall forest products marketplace. Currently, private forest owners have long-established customers for the trees they grow on their lands: sawmills, pulp mills, OSB facilities and plywood plants. These customers expand and decrease their wood use over time depending on economic conditions and demand for their manufactured products.

Over the past few years, wood bioenergy projects garnered headlines, benefited from targeted legislation and financing programs, and produced dozens of failed and successful plants across the U.S. This provides data and information to evaluate the status of wood bioenergy demand relative to the established forest industry. It also frames the context for considering the implications from bioenergy projects related to wood raw material prices, forest management strategies and the long-term sustainability of U.S. forests.

This paper quantifies the current baseline for forest industry wood consumption in the U.S. in order to provide context for wood bioenergy market developments and research. When tracking wood demand and timber markets, we look not only to the past and to the future for guidance, but also to the side – peripherally – to gauge performance across wood-using markets and sectors. Specifically, we address the following questions:

- What is the current status of wood demand from bioenergy in the United States and how has it evolved over the past five years?
- What is the current status of traditional wood demand from the forest products industry and forest supplies/growth in the U.S.?
- What are reasonable expectations for wood bioenergy growth in the U.S. relative to the forest products industry over the next ten years?

Ultimately, establishing the current forest industry baseline and specifying what is "doable" and "operable" in regional U.S. bioenergy markets provides a factual basis for evaluating how wood bioenergy markets could affect forest supplies. This also allows us to evaluate recent research and scenarios applied to forward thinking analysis related to wood bioenergy markets.
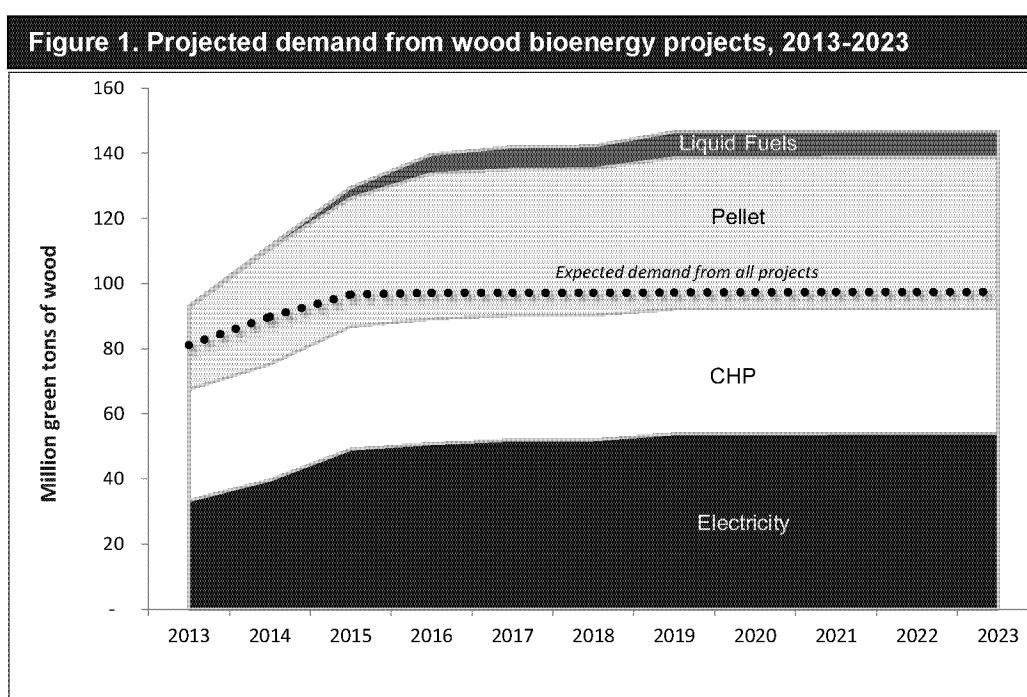
Wood Bioenergy Market Development

In 1972, the Club of Rome commissioned *The Limits to Growth*, a book which explored the interaction between exponential growth and limited resources. The book concluded that the world would reach its limit within 100 years of publication, resulting in a massive decline of population and industrial capability. While criticized at the time, key elements of the research – such as those associated with population growth and CO_2 levels – held up, reinforcing historic relationships between resources and growing populations. However, the research understated the role played by prices and markets in allocating resources.

Lessons from this research apply when evaluating the development of wood bioenergy markets. While market forces and policy decisions struggle to coexist, the actual growth of bioenergy relative to available resources can be understood. Wood bioenergy projects must successfully navigate logistic challenges and access to wood raw materials within the context of existing forest industry markets. To a critical extent, assessing bioenergy markets is an exercise of measuring size and performance relative to the existing forest industry.

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Analysis of projects "on the ground" frames our understanding of what is possible and viable for growing wood demand from bioenergy. Forisk uses a two-part screening methodology to estimate project viability by technology and by status. If the technology is viable today (such as wood pelletizing technology or wood to electricity) then the project passes the technology screen. For example, cellulosic ethanol technologies do not currently pass the technology screen. The status screen evaluates projects based on where they are in the development process. If a project has two or more necessary permits, contracts, or financing commitments, then it passes the status screen. "Likely" projects are those that pass both screens. (See Appendix A for additional details on the project screening methodology).

Since 2010, multiple wood bioenergy projects in the United States have opened, closed or advanced towards operational viability. However, the implications on potential wood use were modest. Total potential wood use from announced and operating projects increased 3% while potential wood use from operationally "viable" projects increased approximately 10%. As of April 2013, *Wood Bioenergy US* counts 456 announced and operating wood bioenergy projects in the U.S. with total, potential wood use of 125.0 million tons per year by 2023 from all feedstocks, including forest materials and mill residuals (Figure 1). Based on Forisk analysis, 293 projects representing potential wood use of 75.4 million tons per year pass basic viability screening.

Figure 1. Projected demand from wood bioenergy projects, 2013-2023

Source: Forisk Consulting
Note: largely excludes cogeneration projects at forest products facilities.

Analysis and tracking of wood bioenergy projects by technology type and region affirm the slow, stuttered development of wood bioenergy markets in the United States. These markets depend on legislative mandates or remain uncompetitive with traditional forest industry manufacturers or more economic energy sources such as natural gas. Two types of projects have led progress in wood bioenergy markets over the past three years. First, industrial combined-heat-and-power (CHP) plants and firms that build industrial CHP facilities and either use the electricity and heat/power produced for their own manufacturing plants or sell it to neighboring facilities. This
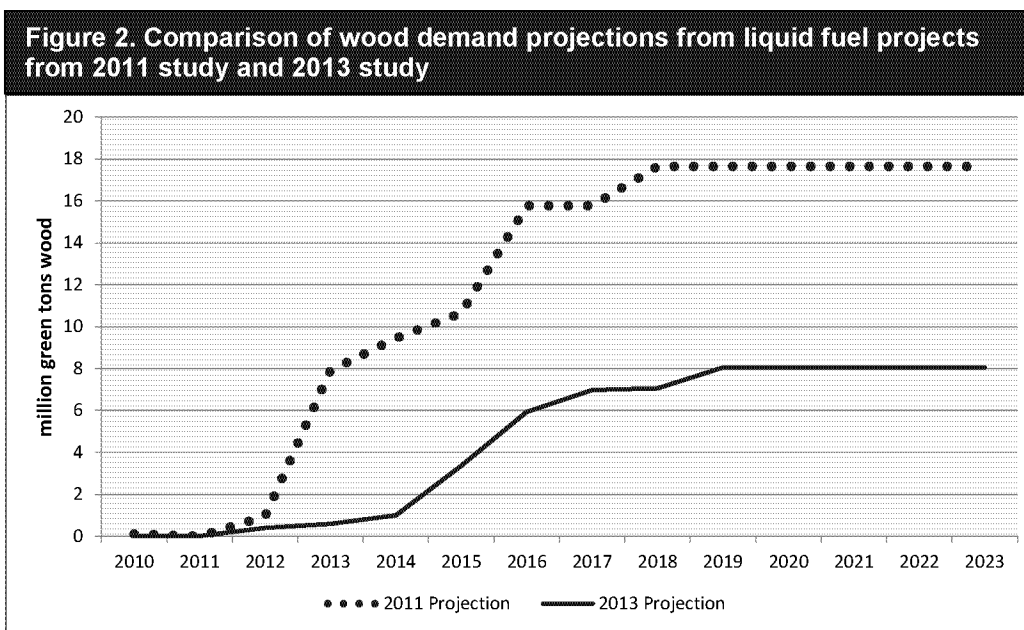
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includes some government-sponsored completed CHP projects, such as Oak Ridge National Laboratory and the Savannah River Site. Second, pellet plants targeting both the smaller domestic and growing export markets have made progress. Export pellet plants are selling to European utilities to help them meet renewable energy requirements. In addition, there are select independent power producers who continue to build electricity plants.

A review of the primary wood bioenergy technologies and project types reinforces these themes.

Wood-Based Liquid Fuels

Research by private and public organizations emphasizes the problematic development of the wood biofuels sector. In 2011, Forisk and the Schiamberg Group evaluated 36 publicly-known wood-using biofuels projects in the U.S. concluding that they would take eight to 11 years longer to develop than estimated by the projects themselves while singling out projects with drop-in fuels and specific technology types as having investment potential for investors. A review of the 36 projects from the 2011 study re-affirms that biofuels from wood is not a mainstream reality (Forisk 2012). As of April 2013, 13 of the original 36 projects have been cancelled and 12 remain in the planning or construction stages. Four have been shut down. In total, 27 of the 36 projects (75%) have been cancelled or have failed to advance. Unfavorable project economics and insufficient financing are the primary reasons for the cancellations and shut-downs.

Newly announced wood biofuel projects have become increasingly less ambitious and less relevant to forest industry firms and timberland investors. Analysis comparing projects in 2013 to those from 2011 find that current projects use less wood and scale at smaller production levels. Meanwhile, the traditional forest products industry is reopening closed plants and building new capacity in response to increasing housing demand. Analysis of potential wood use highlights the minimal relevance of the biofuels projects to timberland investors in the U.S. today and over the next ten years (Figure 2). Even the U.S. Forest Service set aside the wood biofuels sector in its December 2012 projections for the U.S. forest products industry (Ince and Nepal 2012). They note, "The scale of such technologies remains highly uncertain, so we do not include projected timber demands for such technologies."

Figure 2. Comparison of wood demand projections from liquid fuel projects from 2011 study and 2013 study

Source: Forisk Consulting

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Wood Pellets

The wood pellet sector highlights the localized and technology-dependent nature of wood bioenergy market growth and potential. Wood pellet project development in the South leads the U.S. across nine regional wood bioenergy subsectors: pellets, liquid fuels and electricity/CHP in the North, South and Pacific Northwest (Figure 3). Of current pellet project announcements, 89% of the total production by 2023 would be exported to European markets. However, the ability of U.S. firms and exporters to successfully produce wood pellets is limited by critical factors associated with port access and the economics of pulpwood markets. Location-based issues and raw material prices and availability drive due diligence efforts to a short list of logistically attractive wood basins that include varying levels of direct, unyielding competition for residual chips and pulpwood roundwood. These factors limit the potential growth of wood pellet producers within the United States.

Figure 3. Relative growth of wood bioenergy activity since 2010
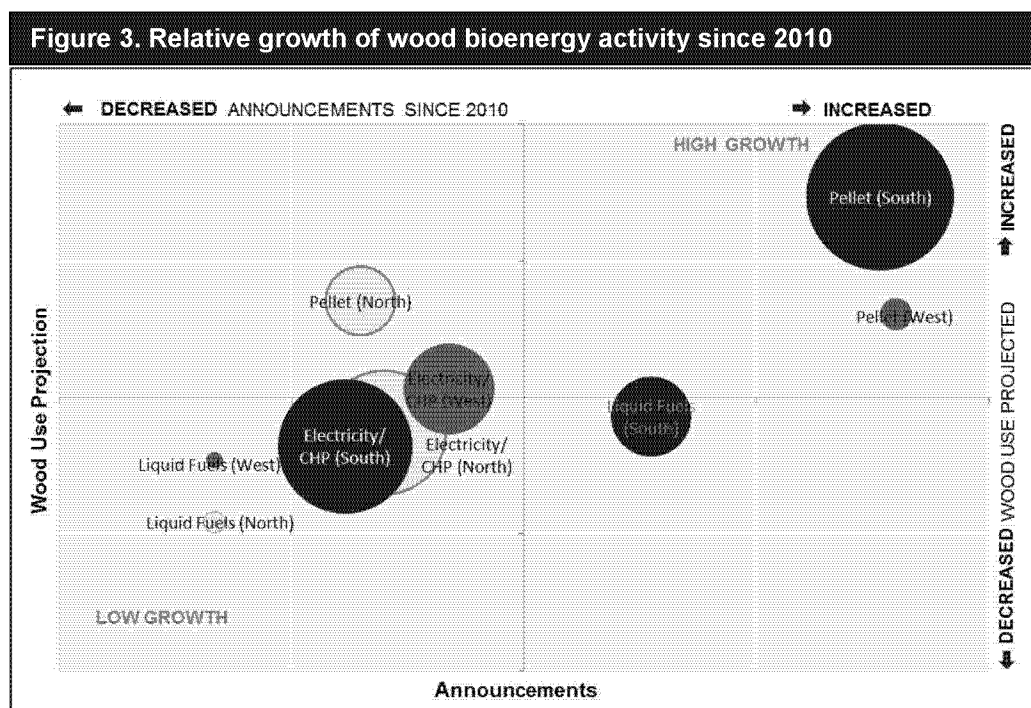
Source: Forisk Consulting

Three factors help explain why pellet projects in the South lead the U.S. First, wood pellet plants rely on known, proven technologies. This facilitates the financing and development of new projects. Second, pellet projects require lower levels of capital investment relative to liquid fuel and large scale electricity projects. Pellet projects require $150 million or less while the others require hundreds of millions of dollars. Third, project developers and investors are responding to actual demand from actual customers (in Europe). For the pellet projects announced as of April 2013, 55% (32 of 58) focus on the export markets. For the South, export oriented projects account for 93% of the total.

Wood Electricity

Large scale wood-to-electricity in the United States, shaped by monumental energy policies, began in the 1970s (Mendell and Lang 2012). However, as of May 2013, the United States does not have a federal mandate for renewable electricity, or renewable energy standard (RES). The lack of a federal RES slowed the development of stand-alone wood-bioelectricity plants.

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While public policy appears critical in advancing wood bioenergy, market factors related to financing and project economics play instrumental roles in stalling wood electricity. Failure to secure off-take (PPA) agreements, the inability to obtain financing, and plentiful and cheap natural gas supplies have reduced expectations associated with wood-based biopower in the United States over the next ten years. Of the 151 projects on hold, shut down or canceled as of April 2013, 84 (56%) are wood-to-electricity or CHP projects.

Figure 4 summarizes the overall progress of wood bioenergy projects in the U.S. Projects have been put on hold, shut down, or canceled for a variety of reasons, including financing, the relatively high costs of woody feedstock compared with low natural gas prices, regulatory uncertainty, and difficulties obtaining economically sensible PPAs. In limited instances, local opposition to bioenergy projects has also slowed bioenergy market development.

Figure 4. Bioenergy plant progress, December 2010 – April 2013
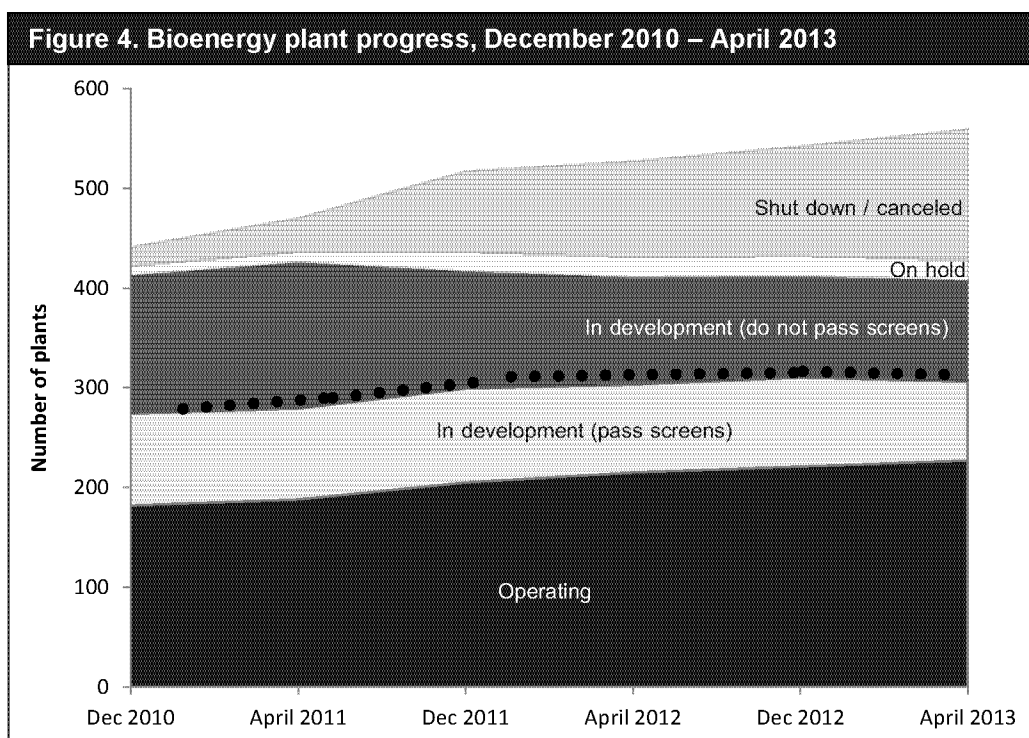
Source: Forisk Consulting

Recent events related to the preference for natural gas support a story consistent with the historical evolution of U.S. energy markets. *Wood for Bioenergy* (Mendell and Lang 2012) details the central role of wood as an energy feedstock in the 1800s. However, markets shifted as cheap and plentiful coal replaced wood, establishing and repeating a trend of cheap energy quickly substituting for costly energy.

Looking Forward: Context for Potential Wood Bioenergy Market Growth

The economics of pulpwood markets are increasingly important for wood bioenergy projects. Current pulpwood users already buy nearly 140 million tons of pulpwood and in-woods chips in the South alone. Local wood supply and demand dynamics dictate market responses to new

entrants. Aggregate pulpwood and chip demand in the U.S. comes from three categories of end uses[1]:

1) **Paper and paperboard**, which includes all paper, containerboard and cardboard types produced in the U.S.
2) **Oriented strand board (OSB),** a type of engineered structural panel made from low-value wood raw material; strands, or long chips, of wood are glued together in a specific orientation to form panels. OSB is used in construction and directly competes with plywood.
3) **Wood use for bioenergy,** most woody biomass facilities intend to use the by-products of forestry operations for feedstock; however, some will require pulpwood-sized roundwood or clean pulp chips.

Multiple firms and government agencies develop projections of how wood demand from biomass firms will grow in the future. For example, the U.S. Forest Service released the 2010 RPA Assessment (USDA Forest Service 2012). The 1974 Forest and Rangeland Renewable Resources Planning Act required that the Forest Service prepare information for the American public regarding the future of America's forests and how they would meet resource demands. The RPA Assessment includes information on the current status and projected future state of forests in the U.S. on a 10-year cycle, as well as projections of wildlife and fish, water, outdoor recreation, and other natural resource issues.

As part of its projections for forests and forest products, the RPA Assessment tests multiple scenarios regarding wood bioenergy development. The scenarios, based on Intergovernmental Panel on Climate Change (IPCC) scenarios of global energy use, start in year 2020 and go through 2060. The use of IPCC scenarios provided a framework for working in parallel with other modeling efforts conducted in the scientific community at the time of the RPA research from 2005 through 2010. It also provided a broad range and breadth of possible outcomes without taking a position on likelihood. In addition to the IPCC scenarios, the RPA includes a historical fuelwood (HFW) scenario that is based on the relationship between fuelwood use and GDP in each country.

During and following research associated with the RPA, the U.S. economy declined as did wood use associated with forest products manufacturing. To address recent market events and other baseline assumptions in the RPA, U.S. Forest Service researchers Peter Ince and Prakash Nepal (2012) published research to address three issues with the 2010 RPA Assessment: 1) to account for the economic recession in the projections; 2) to account for changes in the bioenergy outlook and low natural gas prices; and 3) to consider currency exchange rates in their projections. Ince and Nepal follow the same methodology as the HFW scenario in the RPA assessment, with updated underlying assumptions, including housing starts.

Forisk Consulting projects wood use from bioenergy projects using a bottom-up approach in its *Wood Bioenergy US* (WBUS) publication. WBUS tracks over 450 announced and operating wood-using bioenergy projects. Forisk projects the estimated wood use of each of these projects and sums the total wood use by each project until 2023. Forisk does not project bioenergy demand growth beyond the next 10 years.

Major differences exist in the assumed levels of wood demand for the IPCC scenarios and the work by Ince and Nepal and Forisk Consulting. As a result, the highest demand scenario from

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[1] Another important forest industry sector that produces composite panels such as MDF is not included here because it relies primarily on manufacturing residuals for its raw material. This paper focuses on pulpwood and in-woods chips delivered directly from the forest.

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the RPA projects significant growth of wood bioenergy in the U.S.; wood demand for bioenergy climbs to levels that are 5 times higher than all other wood uses by 2060. The Ince and Nepal projection and HFW scenario from the RPA fall closer in line to independently developed projections by Forisk in *Wood Bioenergy US* than the IPCC scenarios (Figure 5).

Figure 5. Comparison of wood bioenergy demand scenarios from RPA, Ince and Nepal, and Forisk Consulting
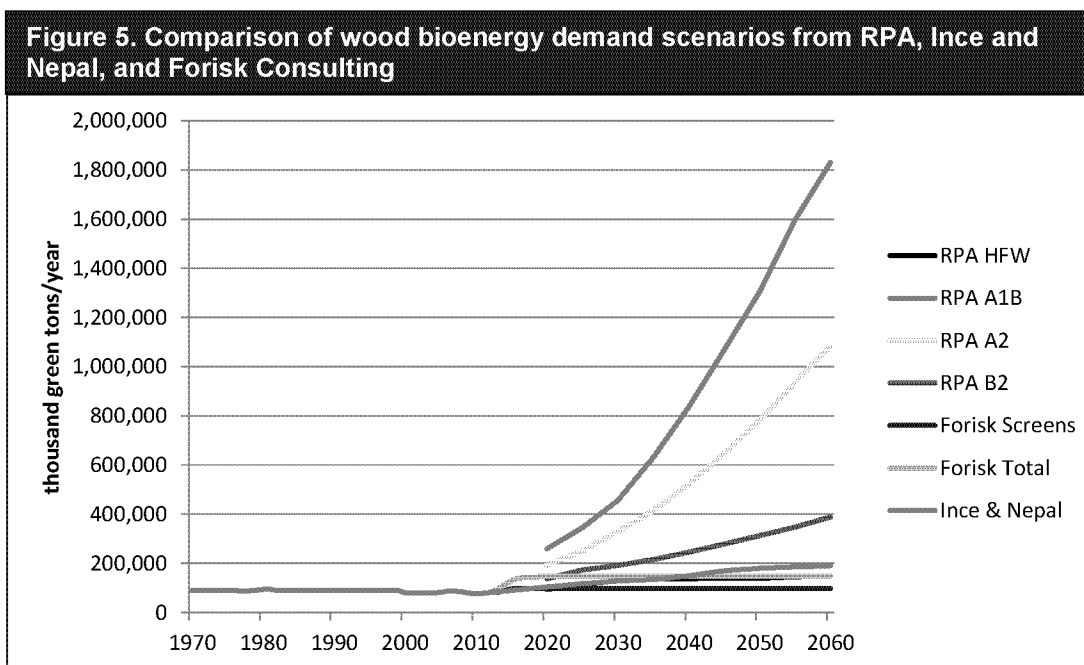
Sources: USDA Forest Service, 2012; Ince and Nepal, 2012; Forisk Consulting, 2013
Note: Forisk projections include operating cogeneration facilities at forest products plants. All projections exclude "fuelwood" estimates and include mill residues, pulpwood, and logging residues.

Analysis of the underlying assumptions highlights the disconnect between broad-based, demand-driven scenarios that assume aggressive growth in wood demand from bioenergy in the United States and assessments of what may be operable and "doable" on the ground. The IPCC-based scenarios in the RPA are not realistic in that they do not account for operational or market constraints. Notwithstanding assumed wood demand for bioenergy, the industry will likely not have the resources, technologies or competitive economics to deliver energy to the U.S. market at the assumed levels.

Bioenergy projections that account for historical relationships (HFW in the RPA and Ince and Nepal) more closely match the research by Forisk that relies on actual announcements by biomass firms. The reality of market-based scenarios further underscores the recent emergence of cheap and plentiful natural gas which has replaced planned wood bioenergy projects and capacity. In short, bioenergy projects participate in a competitive market for capital and wood raw materials, and the present outlook suggests that domestic growth in new sources of bioenergy from wood will be modest.

Forest Products Sector Demand

Analysis of forest inventories in the United States highlights how forest growth continues to outpace forest removals. Analysis of U.S. Forest Service inventory data by region confirms a continued accumulation of forest volume across public and private forest ownerships in all U.S. regions. While the specific supply and demand dynamics vary for specific local markets and

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during specific local natural catastrophes, the aggregate assessment of forest volume trends remains unchallenged: forest inventories in the U.S. today exceed those of ten, twenty and fifty years ago (Figure 6).

Figure 6. Growing stock for US, all species, public and private ownership of timberlands
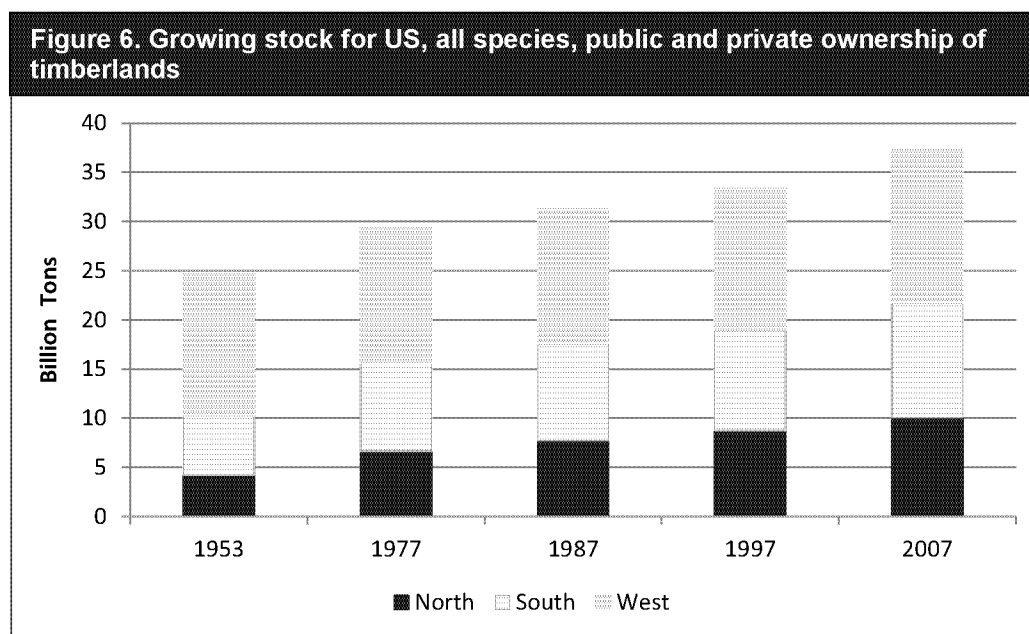
Source: US Forest Service (RPA Assessment) Smith et al. 2009

Total wood demand in the United States has declined in recent years. According to the United Nations, demand for "industrial" roundwood – the logs used at manufacturing facilities – declined 33% from 2005 to 2011, from 508 million tons to 341 million tons per year. According to the U.S. Forest Service, demand for roundwood – as measured by forest removals – declined 34% from 2005 to 2011, from 491 million tons to 326 million tons per year. And according to forest industry analysis and forecast work conducted by Forisk, demand for wood declined 31% from 2005 to 2012, from 500 million tons to 347 million tons per year.

Each of these sources indicates rising demand for wood over the past two years as markets continue to strengthen. As of year-end 2012, for example, U.S. Forest Service and Forisk analysis indicate forest industry demand for wood increased between 7 and 9% since 2011. Overall trends associated with (1) U.S. lumber consumption increasingly sourced by U.S. manufacturers at the expense of Canadian producers and (2) strong export markets for specialized pulp products and softwood lumber support projections of wood demand for the U.S. forest industry returning to 500 million tons per year by 2020. In addition, consensus exists across databases and studies from private researchers, the U.S. Forest Service, and public international databases that the supply of industrial roundwood in the United States exceeds this level of demand from manufacturing facilities and will likely continue to do so in the future.

The Ince and Nepal (2012) and Forisk scenarios show the marginal increase in wood demand for forest materials (i.e. pulpwood and logging residues) from bioenergy projects compared to the overall forest industry (Figure 7). In 2023 pulpwood and logging residue wood use from viable bioenergy applications could be as much as 9% of the total wood use of the forestry sector or as little as 4%. The vast majority of wood use will still be from the traditional forest products sector.

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Figure 7. Projected wood demand by forest products and wood bioenergy sectors in U.S.
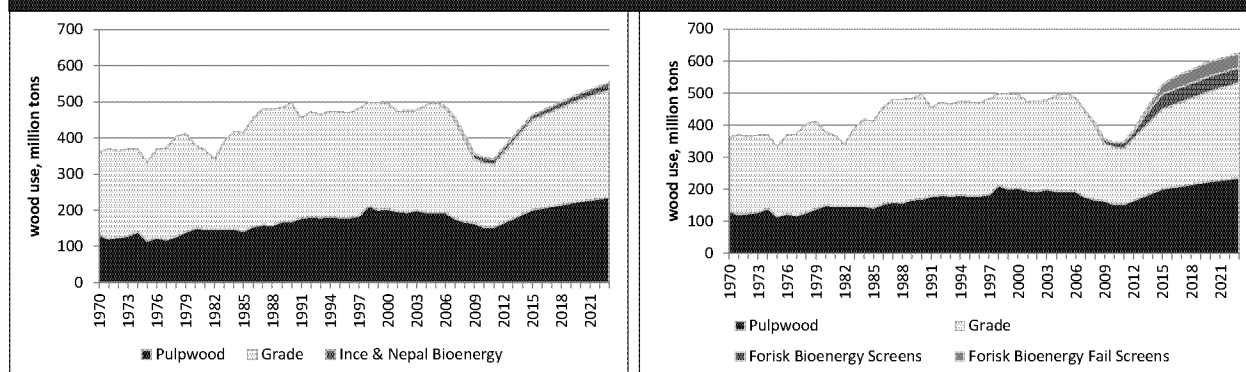
Source: Ince and Nepal, 2012; Forisk Consulting
Note: bioenergy projections include pulpwood and logging residues only; exclude mill residues and fuelwood.

Although wood demand from the forest products and bioenergy sectors is projected to increase, forest supplies are also projected to increase in aggregate (Figure 8). Future forest supplies from Ince and Nepal (2012) show increasing inventories; in contrast, the RPA assessment projects decreasing forest inventories. The baseline outlook for housing and demand for wood was lower in Ince and Nepal's model than in the RPA, and Ince and Nepal accounted for decreased demand for wood during the recession, while the RPA assessment did not. Also, Ince and Nepal projected much lower demand for wood for energy applications than most RPA scenarios (except HFW). Also, the two research assessments used different modeling approaches for forest supplies. The projections by Ince and Nepal account for recent events that affect wood use and include a more realistic wood bioenergy demand scenario than the RPA. Of the two supply projections, we view the Ince and Nepal projection as the most likely.

Forest supply projections by the U.S. Forest Service show that wood bioenergy projects pose no negative impact at a regional level. Bioenergy projects could have impacts at local levels depending on a variety of factors, including landowner dynamics, proximity to existing manufacturing facilities, prices, disturbance and other variables. Such variables are typically considered during project development and help determine the economic viability of a project.

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Figure 8. Projected forest supplies from RPA Assessment (left) and Ince and Nepal 2012 (right).
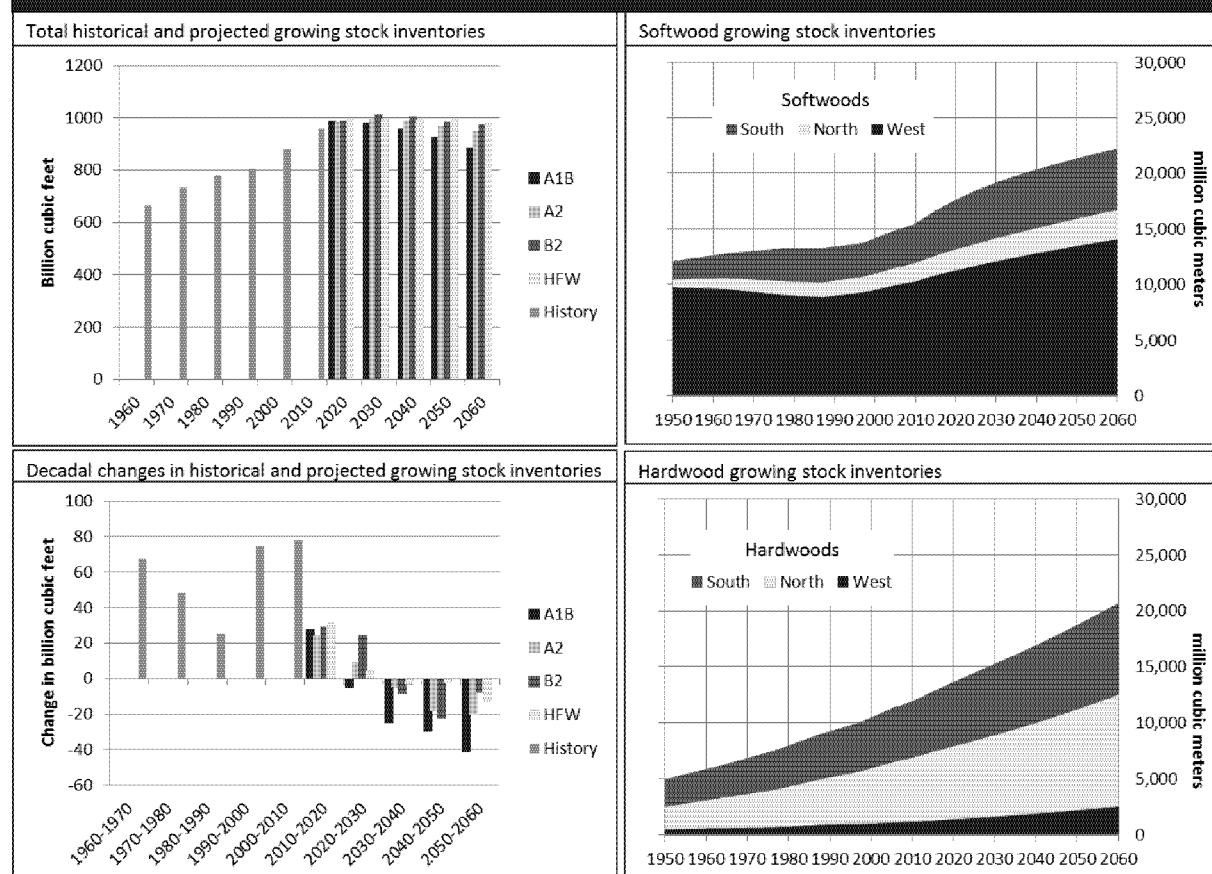
Sources: USDA Forest Service, 2012; Ince and Nepal, 2012

Conclusions

This paper quantifies the current baseline for forest industry wood consumption in the U.S. to provide context for wood bioenergy market developments and research. Specifically, it addresses questions of wood demand from bioenergy, wood demand from the forest products industry, and reasonable expectations for wood bioenergy growth in the U.S. relative to the forest products industry over the next ten years. Establishing the current forest industry baseline and quantifying what is "doable" and "operable" in regional U.S. bioenergy markets provides a factual basis for evaluating how wood bioenergy markets could affect forest supplies.

Key findings from this research include:
* Analysis and tracking of wood bioenergy projects by technology type and region affirm the slow, stuttered development of wood bioenergy markets in the United States.
* Since 2010, total potential wood use from announced and operating projects increased 3% while potential wood use from operationally "viable" projects increased approximately 10%. Based on Forisk analysis, 293 projects representing potential wood use of 75.4 million tons per year by 2023 pass basic viability screening. This estimate includes all woody feedstocks, including pulpwood, logging residues, and mill residuals.

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- Consensus exists across public, private and international studies and data sources regarding the size and status of the U.S. forest products industry. Demand for "industrial" roundwood – the logs used at manufacturing facilities – is approximately 500 million tons per year during normal economic conditions.
- Wood bioenergy scenarios developed by the IPCC and applied to models of U.S. forests have major flaws with respect to failures to account for the economic recession and the viable scale of actual and operable wood bioenergy projects in the United States.
- Viable wood bioenergy scenarios developed separately by U.S. Forest Service researchers and Forisk find the marginal increase in wood demand for pulpwood and logging residues from viable bioenergy projects compared to the overall forest industry in 2023 could be as much as 9% of the total wood use of the forestry sector or as little as 4%. The vast majority of wood use will still be from the traditional forest products sector.

Assumptions regarding market viability and what is operationally "doable" remain critically important when making projections of wood bioenergy impacts in the United States. This research reaffirms the importance of considering realistic scenarios that have basis in actual market transactional data and account for market responses. Wood bioenergy projects will likely have no negative impact on forest supplies in the aggregate, while more specific impacts will likely occur locally in individual wood baskets and timber markets.

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Appendix A. Screening Operating and Announced Wood Bioenergy Projects

This appendix summarizes the methodology detailed in a white paper commissioned by NAFO in 2010. The complete paper is available at: http://nafoalliance.org/wp-content/uploads/Forisk-A-Practical-Guide-for-Tracking-Wood-Using-Bioenergy.pdf

Forisk developed a wood bioenergy market screening methodology to assess project viability, and documented this method in a white paper published by the National Alliance of Forest Owners (Mendell and Lang 2010). The basic methodology for the screen relies on two criteria for wood-consuming projects:

■ Technology: projects that employ currently viable technology pass the technology screen. These include pelletizing technology and wood-to-electricity projects.

■ Status: projects that are operational, under construction, or received or secured two or more necessary elements for advancing towards operations pass the status screen.

The following checklist can be applied to replicate Forisk's project-by-project screening to assess if projects are likely to succeed:

Step 1: Technology Screen
Is the project a wood to electricity project, a pellet project, or a project that uses another technology that is commercially viable today?
If YES, then go to Step 2: Status Screen. If NO, stop – project fails the screen.

Step 2: Status Screen
Is the project operating?
If YES, then the project passes the screen. If NO, go to question 2a.

2a. Is the project under construction?
If YES, then the project passes the screen. If NO, go to question 2b.

2b. Does the project have two or more of the following?

☐ Secured site

☐ Financing

☐ Air permit

☐ Engineering Procurement and Construction (EPC) contract

☐ Power Purchase agreement or off-take agreement

☐ Public Service Commission approval

☐ Interconnection agreement

☐ Wood supply agreement

If YES, the project passes the screen and demonstrates momentum towards initiating construction. If NO, then the project fails the screen and is not considered likely to succeed at this time given publicly-available information.

FORISK
CONSULTING

A Regional Approach to Biogenic Carbon Accounting Using FIA Data

March 7, 2014

Paul C. Van Deusen, Ph.D.
Alan A. Lucier, Ph.D.
NCASI

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EPA's 2011 Draft Accounting Framework

Key elements of the draft AF include:

1. Anyway emissions (certain feedstocks)

2. Analysis of trends in forest C stocks

Forest Inventory and Analysis

- Most important and comprehensive source of data and information about forests in the U.S.

- FIA's "new" Annual Forest Inventory System facilitates analysis of regional trends in forest C stocks.

  - Most states have 10-12 years of data available.

  - Estimates of growth, mortality and removals are not yet available in the West.

Concept for Using FIA Data in Context of Biogenic Carbon Accounting

- Use FIA data to analyze regional trends in Above Ground Biomass (AGB) on *timberlands*.

  - Change in AGB is a good indicator of change in forest C stocks.

  - Below-ground C:

    - Change is difficult to measure.

    - Typically not sensitive to timber harvest unless forest is converted to non-forest use.

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EXAMPLE

- **North:** CT, DL, IL, IN, IA, KS, MA, ME, MD, MI, MN, MO, NE, NH, NJ, NY, ND, OH, PA, RI, SD, VT, WV, WI

- **South:** AL, AR, FL, GA, KY, LA, NC, OK, SC, MS, TN, TX, VA

- **SouthWest:** AZ, CO, NV, NM, UT

- **Pacific Coast Northwest:** CA, OR, WA, ID, MT

EXAMPLE

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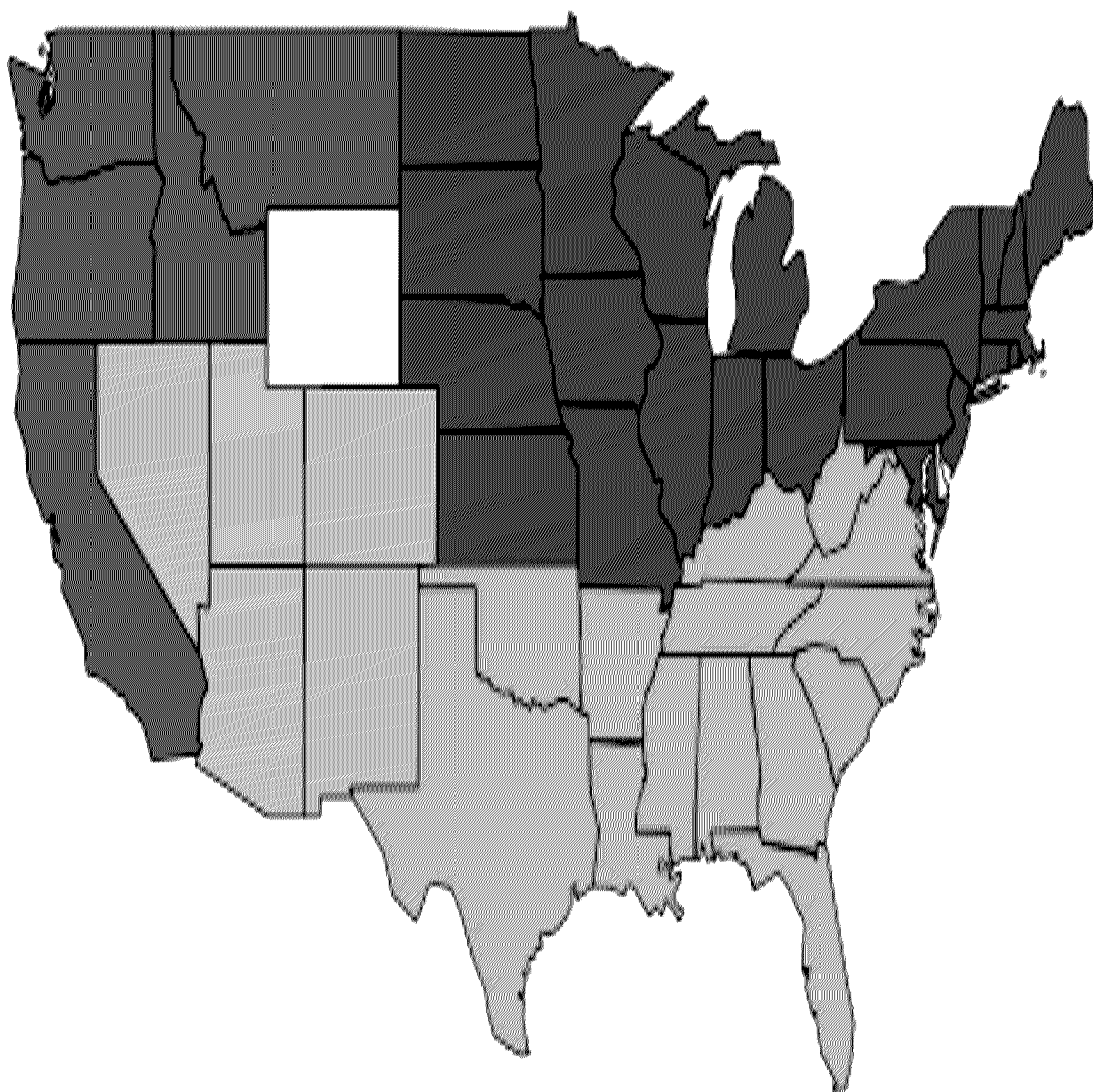
AGB (t/ac) on Timberland
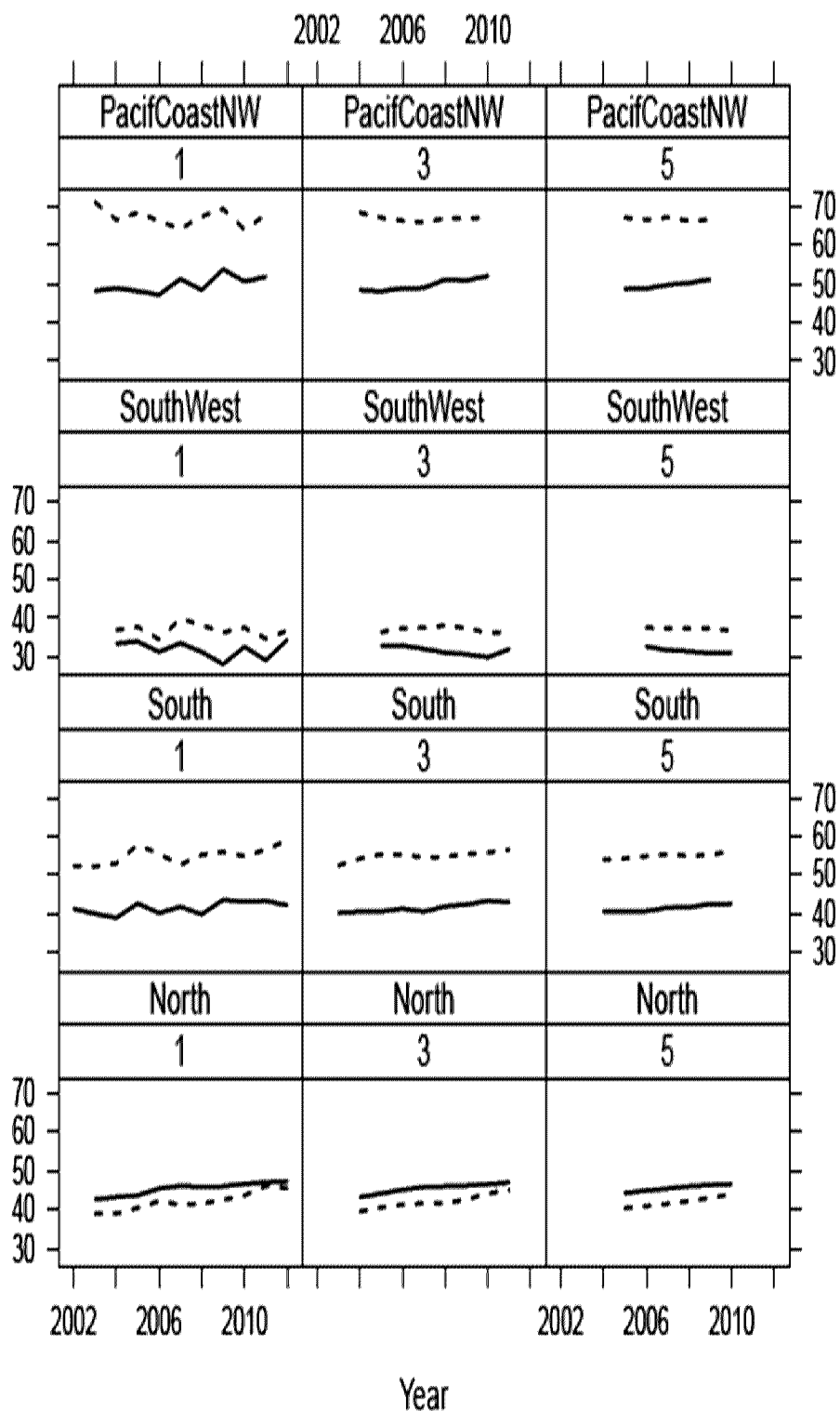
dash line=Public TL, solid line=Private TL

Per Acre AGB vs. Total AGB

- Total AGB = (Forest Area) X (AGB)

- Changes in forest area over short time periods are difficult to estimate accurately.

- Losses of forest area are typically caused by development or agricultural expansion, not changes in timber harvest rates.

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Trend in US forestland area, 1630 to present
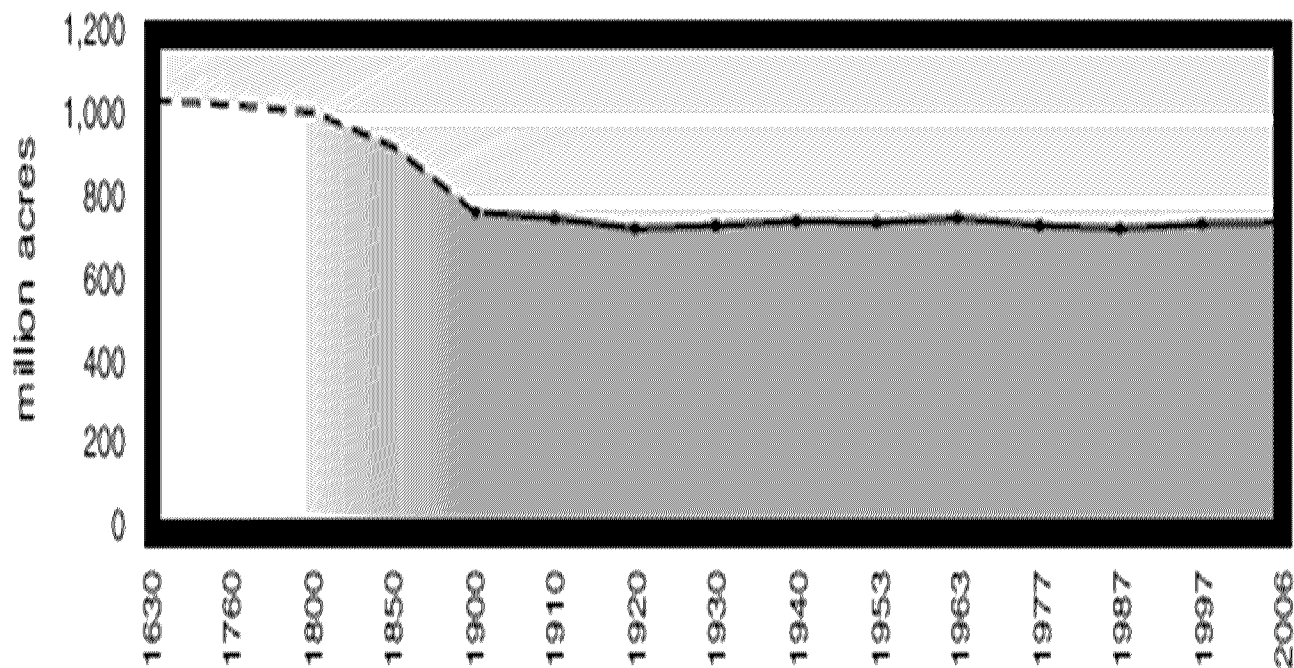
Note: Data prior to 1950 are based on historical evidence, not field sampling.
Source: USDA Forest Service, Forest Inventory Analysis Program. 2006.

From: *State of America's Forests*.
Society of American Foresters.

Advantages of AGB Per Acre

- Each FIA plot provides a per-acre estimate.

- Harvesting affects AGB per acre.

- Large numbers of FIA plots reduce uncertainty in regional estimates of mean AGB.

- Analysis of AGB per acre provides insights into differences in forest status and trends among regions, owner classes, forest types.

Integrating AGB into 2011 Draft Accounting Framework

- Divide available FIA data into a Base Period (BP) and an Assessment Period (AP).

- Compute mean AGB_{BP} and AGB_{AP}

- Use AGB_{BP} and AGB_{AP} to compute a Regional Forest Carbon Factor (RFCF)

Base Periods and Assessment Periods

Region	Base Period	Assessment Period
North	2003 - 2007	2008 - 2012
South	2002 - 2007	2008 - 2012
South west	2004 - 2008	2009 - 2012

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AGB in Base Period and Assessment Period:
Private Timberland (t/ac)

Region	AGB$_{BP}$	AGB$_{AP}$
North	44.7	46.6
South	40.7	42.6
South west	32.6	31.0
PCNW	48.8	51.4

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Regional Forest Carbon Factors

- RFCF = 0 if $AGB_{AP} \geq AGB_{BP}$

- RFCF > 0 if $AGB_{AP} < AGB_{BP}$ due to bioenergy

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Regional Forest Carbon Factors

- RFCF Value if $AGB_{AP} < AGB_{BP}$ due to bioenergy

$$RFCF = 1 - (AGB_{AP} / AGB_{BP})$$

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Net Biogenic Emissions (NBE)

- NBE = RFCF x (PGE − AVOIDEMIT − PRODC − SEQP)

  ❖ BAF = NBE / PGE

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Net Biogenic Emissions (NBE)

- NBE = RFCF x (PGE − AVOIDEMIT − PRODC − SEQP)

    ❖ BAF = NBE / PGE

    OR

- NBE = RFCF ($CO2_{BIO}$ − AVOIDEMIT)

    ❖ BAF = NBE / $CO2_{BIO}$

Next Steps

- Identify and evaluate options for assessing role of bioenergy in AGB trends when $AGB_{AP} <$ AGB_{BP}

  - For example, examine FIA data on forest growth, removals, and mortality (GRM)

  - Substantial amounts of GRM data available for North and South; not yet for SW and PCNW.

  - In SW and PCNW, examine alternative forest health metrics and GRM estimates produced for RPA Assessment.

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GForest Map
Dead Standing Basal area (ft2)
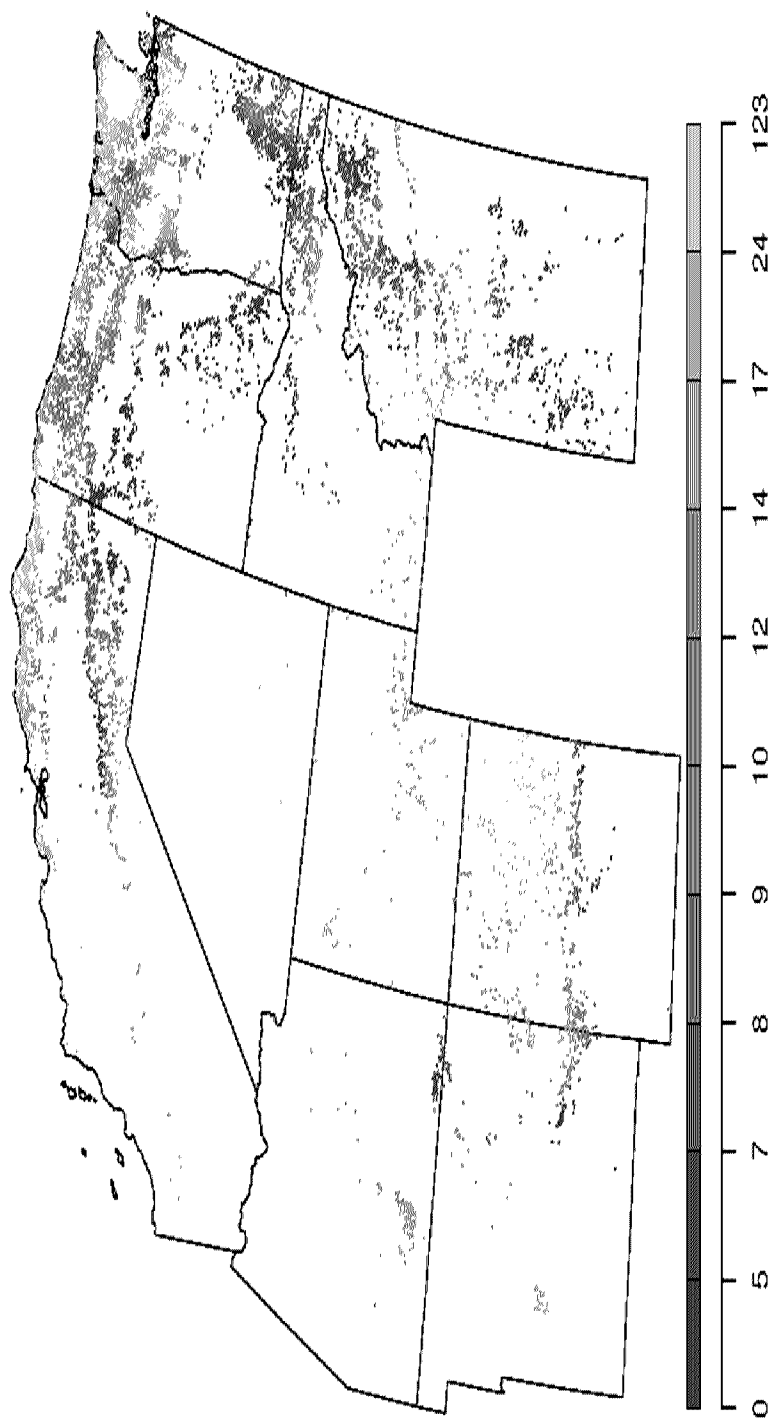
Summary

- Annual FIA data are available for the lower 48 states and can be used to produce accurate annual estimates of AGB (t/ac) for large regions in a Base Period and an Assessment Period.

- Differences between AGB_{BP} and AGB_{AP} can be used to compute Regional Forest Carbon Factors that are easily integrated into EPA's draft 2011 Biogenic Carbon Accounting Framework.

From:	Jordan, Scott
To:	Ohrel, Sara
Sent:	3/7/2014 7:09:18 AM
Subject:	RE: Draft Framework Main Document Review Q&A
Attachments:	Biogenic CO2.DRAFT Framework main report 2 25 14_clean.SJJ notes.2.25.14+3.6.14.docx

Here you go. You can find my questions and comments quickly by searching for "SJJ"

Also, because I did not identify any significant issues that I thought Brian and/or Elliott needed to weigh in on, there is a chance that they may decide not to review this. One way or another, I will provide a full set of OGC comments (or confirm that this is it), by Tuesday.

Scott Jordan
202-564-7508
_____

From: Ohrel, Sara
Sent: Thursday, March 06, 2014 3:16 PM
To: Jordan, Scott
Subject: RE: Draft Framework Main Document Review Q&A

Thanks for taking the time to review it and the heads up about status, Scott. Sure, please feel free to send it along as a preview (I will wait to receive the consolidated ones to edit from later). I really appreciate it!
Sara

From: Jordan, Scott
Sent: Thursday, March 06, 2014 3:10 PM
To: Ohrel, Sara
Subject: RE: Draft Framework Main Document Review Q&A

Thanks.

By the way, I have finished my review of the draft framework document and sent those comments on to Brian and Elliott to see if they have anything to add. My comments were pretty minor: a few typos and minor wordsmithing comments that you probably have already corrected, and 2-3 questions/comments that raise minor points for your consideration.

My plan is to hold my comments until I see what Brian and Elliott have and then send you one set of consolidated comments from OGC. But, if you would like a "preview" I would be glad to send you the document with my comments.

Scott Jordan
202-564-7508
_____

From: Ohrel, Sara
Sent: Thursday, March 06, 2014 2:57 PM
To: Jordan, Scott
Subject: RE: Draft Framework Main Document Review Q&A

Hi Scott,

Sara

From: Jordan, Scott
Sent: Thursday, March 06, 2014 2:56 PM
To: Ohrel, Sara
Subject: Automatic reply: Draft Framework Main Document Review Q&A

Ex. 6 - Personal Privacy

Sara

Sara Bushey Ohrel
Climate Economics Branch
Climate Change Division
U.S. Environmental Protection Agency
Phone: (202) 343-9712
Cell: (202) 341-6748

--this email is deliberative--do not distribute or cite--

Hello everyone,

Thank you all for your continued support on this biogenic assessment project. Attached you will find the updated draft biogenic assessment framework report for your review (actually I am including 2 versions: one in which I include and respond to Robert's comments on an old draft as well as our responses to some OTAQ questions and a clean version for those that would like to work off that instead. We appreciate you offering your time and feedback on this draft report.

This document contains sensitive technical content, so please do not share or cite this document or its contents beyond those members of your team working on this project (Robert and Justin, you can share it with Kate, Katie, Marion, Steven, and others).

We ask that you send us your comments no later than 3/11/14. RTI, please consolidate the comments from your team to help us with version control and our goal of ensuring that all comments will receive due consideration.

We can schedule a post-review call to discussion your questions and comments if you are interested.

Thank you again,

Sara on behalf of the CCD Biogenic Study Team

Sara Bushey Ohrel
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